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THE RIFLE—ITS PROBABLE INFLUENCE ON MODERN WARFARE.

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IN offering to the Institution a Lecture upon the subject of the Rifle, I desire to separate my remarks under two headings, viz., what I state as matter of fact, and what as matter of opinion. The latter is open of course to agreement or disagreement on the part of all who have considered the subject, and nothing will in my idea conduce more to correct notions upon what *may* and *may not* be expected from the rifle when extensively employed in modern warfare, than free, open discussion upon every thing connected with it, as an arm *per se*, and when employed by the class of men in whose hands it is placed.

I would suggest the importance of always regarding the *rifle* and the *soldier* as inseparable in discussing the relative value of different

arms, and by so doing we shall avoid forming, possibly, exaggerated notions of what may be anticipated from the infantry soldier in future warfare.

The history of the rifle is comprised in a few words.

The two great features of the arm, as tolerably well understood at present, are—

1st. The employment of a cylindro-conoidal projectile ; and

2ndly. The grooving or cutting into channels of the interior of the bore of the barrel.

The last circumstance was, in order of chronology, the first done; but for a different object, if we may believe the writers on the subject, to what it is employed for at present.

It is stated generally, that the rifle, or grooved barrel, or (French) carabine, was invented previous to 1498; and the inventor is said to have been a certain *Gaspard Zollner*, of Vienna.

The discovery arose out of the following circumstances.

This arm previous to being grooved had been constructed as an experiment to load at the muzzle (the early form of all fire-arms being breech-loaders), and it was soon found out that the tighter the bullet fitted the better was the practice at the target. The loading, however, with these tight bullets, particularly after the bore had become foul, was anything but easy, and in fact required the assistance of a mallet and strong iron rammer.

Accident pointed out that the loading was easier when the bore was badly cut, or when there existed certain grooves in it, left, no doubt, from the inferiority of the boring-bits then used.

The next discovery appears to have been, that, when these channels were twisted spirally round the bore, greater accuracy was obtained in shooting.

Here, however, matters rested ; the phenomenon existed, was recognised, and wondered at. The learned were not, however, there to explain it.

Every description of twist and number of grooves were tried, according to the individual tastes of the manufacturer, but nothing of any moment was done.

Some assert that the idea of lengthened elliptical bullets was enunciated as far back as 1729, and that good results followed their

employment. An isolated experiment or two may have been tried, but it is doubtful whether such really did take place.

The important stage next arrived at, was the scientific explanation of the true value of the spiral groove cut in the bore. The honour of this entirely belongs to our own countryman Benjamin Robins.

In his Principles of Gunnery, &c., there is a complete and satisfactory explanation of the action of the grooves in determining the flight of the bullet. This was, however, connected necessarily with the doctrine of the resistance of the air being very sensible as a powerful agent acting in a direction contrary to that of the ball's flight, and also as a deflecting agent, disturbing its accuracy under the varying circumstances of the ball turning over in its flight, or revolving upon some axis, generally, if not always, not coincident with the line of projection.

The numerous experiments which this great philosopher originated and successfully carried out, at once determined the importance of the grooves in the interior of the bore, and the effect which they caused upon the bullet. I cannot do better than direct attention to his tract on rifled arms, written considerably more than 100 years ago.

Robins seems also to have considered the question of a lengthened projectile for the rifle, and actually mentions the advantage which might be derived from an egg-shaped bullet. The idea was unfortunately not pursued; and at the end of the last century we find the first English army rifle adopted for the Rifle Brigade, with a spherical bullet. This arm had a barrel 2ft. 6in. in length, with a quarter-turn for the grooves. The calibre was what is designated as a 20-bore. The arm was rifled with seven grooves, and generally went by the name of " Baker's Rifle."

In the early part of the present century there was also introduced a rifled arm for cavalry. The barrel was 20 inches in length,—the calibre a 20-bore, and rifled with seven grooves of the same pitch as the last. Only two cavalry regiments were armed with these rifled carbines, viz., the 10th and 7th Light Cavalry; but they were soon discontinued, from being considered as unfit for cavalry service.

Some slight alterations in the sword-bayonet for the army rifle took place about 1827; but no radical change in the system occurred until 1836, when the Brunswick rifle was introduced.

The points to be noticed in this arm are,

Firstly. The adoption of two deep grooves, with a rapid pitch; and,

Secondly. The employment of a belted bullet, to take the grooves, and thus prevent "stripping,"—a circumstance which would otherwise have happened with a rapid pitch of groove.

This was an advance in the right direction, and a positive rotation was thus obtained with certainty. The arm was much improved in shooting, although the loading was not as easy as was required, and a great disadvantage existed in the bullet and cartridge containing the powder being separate in the soldier's pouch.

With respect to the shooting of the early rifles, it was considered good shooting to place twelve consecutive shots within a radius of 12 inches at 150 yards, within 18 inches at 200 yards, and at 300 yards to keep them regularly on a six-foot target.

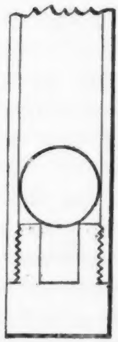
To complete the account of the rifles with spherical bullets, which continued in the English service down to 1851, it is only necessary to state, that subsequent to the French experiments with the conoidal bullet, and the great results obtained over the spherical form, it was proposed to adapt a conical bullet to the Brunswick rifle. This was done as an experiment, and succeeded very well; but at the same time the new arm called the Minié pattern, 1851, was being experimented with, and, the shooting exhibiting greater accuracy with this latter arm, nothing further was done with the Brunswick rifle and conoidal bullet.

FRANCE.

Chronology of improvements in Projectiles which led to the Cylindro-conoidal form.

The difficulty of loading with the spherical bullet, necessarily fitting tight in order to ensure tolerable accuracy, had led the French, during the Wars of the Revolution, to abandon the arm.

Still the attention of numerous military officers was directed to the subject.



At last, in 1827, M. Delvigne proposed a method of loading which should be perfectly easy and simple; in short, as much so as that of the smooth-bore arm.

In order to obtain the expansion, however, he proposed the introduction of a chamber in the bore having a small opening to receive the charge, and furnishing, besides, an annular surface to receive the bullet and allow of its being struck a smart blow with the rammer, and so expanding into the grooves. This bullet was still spherical.

After numerous experiments, and the addition of a wooden sabot to the bullet, and a greased wad, the arm was introduced into the French service, and employed by their troops in Africa.

Next came the invention of the Tige, by Col. Thouvenin, 1842.

The *principle* was similar, though the method of giving the expansion to the bullet different.

Assisted by Capt. Tamisier and Minié, numerous experiments were made with carabines à tige and spherical bullets.

The next great discovery, and the one which at once caused the arm to take an immense stride in advance, was the cylindro-ogival ball.

It is said that M. Delvigne had experimented with the cylindro-conical bullet in presence of Capt. Minié, and that great results had occasionally been obtained. The proper relation, however, which should exist between the number of grooves, their pitch, depth, &c., and their evident dependence upon the weight of projectile, charge of powder, calibre, &c., delayed the introduction of these bullets for a time, until considerable experiments had settled within certain limits the above points.

The facility of loading with the tige, and the excellent results presented by the practice with this bullet, determined the introduction of the carabine à tige and cylindro-conoidal bullet with solid

base in 1846, and the arming with it of the Chasseurs and Zouaves of the African army.

Some years after these last experiments Capt. Minié proposed the adoption of a bullet which should receive its expansion through the influence of the charge on exploding.

This bullet has rather a flatter head, and received an iron cup in the hollow of the base of the bullet. The gas was supposed to drive this cup into the hollow and force the walls of the cavity outwards, thus making them enter into the grooves.

This idea, assisted by some other unrecognised cause, was found on experiment to succeed very well; but the complication which it introduced, viz. that of making the bullet consist of two parts, operated against its definitive introduction. It however gave rise to numerous endeavours to employ the principle of self-expansion, but without the cup, or anything attached to the bullet.

In 1850 the Fusil rayé, with balle à culot, was put into the hands of a certain number of French regiments of the line, and since then the French Imperial Guard have been armed with the old musket rifled, and a bullet without cup, on the self-expansion principle. At present it is understood that the French government are rifling all their smooth-bore arms, and the Russians are doing the same.

The English Minié, pattern 1851, was the result of the experiments conducted in France; and, in fact, was to a considerable extent a copy of a foreign arm. The calibre of this arm was ·702; the bullet was of a cylindro-conoidal form, and was furnished with an iron cup. The total weight of arm was 10¼ lbs.

This arm being still considered too heavy, and the ammunition weighing too much to allow of sixty rounds being carried by the soldier conveniently, the late Lord Hardinge ordered a committee to assemble in 1852 for the purpose of going still further into the question of rifled arms.

This Committee commenced their labours by enunciating what they considered, as military men, should be the object kept in view, viz.:—

"To ascertain the best description of fire-arm for military service, and not merely the best rifle for firing at a mark or for sporting purposes."

All line soldiers requiring to be armed with a rifle of a lighter description than the pattern of 1851, it was, of course, a *sine quâ non* that the arm should not be more difficult to load than the old smooth-bore. Infantry in line must necessarily fire quickly when once deployed and in close action. The necessity, therefore, for an easy-loading weapon, which should be sufficiently accurate at those distances at which infantry deliver their fire, was *absolute*. With this point no doubt kept prominently forward, the idea was held that as large a bore as possible, consistent with carrying a large quantity of ammunition by the soldier, should be adopted, so that a crushing, accurate, and close fire, as well as a rapid one, might be ensured.

The question was a difficult one at that time to settle so as to satisfy the wishes of all parties, but it was no doubt safe to consider the wants of the line infantry soldier first.

This being done, it was competent for the Committee to recommend either the same arm for riflemen proper, or for such corps as might be instructed to fire at long ranges, or else (if, in view of greater simplicity on every hand, they thought it advisable) to recommend the same arm sighted for longer distances for the special rifle corps. This latter was done.

It will be here seen that the Committee balanced the advantages which on the one hand would possibly accrue from the introduction of a more accurate shooting-gun for the special corps, with, on the other hand, the disadvantages of having two patterns of arms. I do not here allude to mere length of barrel, or substitution of sword bayonet for common bayonet, but the alteration of calibre, form of rifling, shape of bullet, &c.

It will be easily comprehended that a military arm has *many conditions* to fulfil. The mere consideration of accuracy beyond what is required for the particular service of the arm might lead to considerable difficulties in other directions, such as hard-loading, quick-fouling, difficulties in manufacture of arm and ammunition, difficulty of repair or of maintenance.

For example, although small calibres with rapid twist and wing-projectiles give greater accuracy, yet fouling takes place sooner, loading becomes more difficult, and finally accuracy is lost. The

French have tried numerous experiments with small calibres and long bullets, the latter increased even to six and seven diameters in length.

After extended experiments, the Committee decided upon recommending the arm which goes now by the name of the Enfield rifle, or pattern 1853 rifle musket.

The points to be noted in this arm are—

1. That the grooves are limited to three.

2. No greater spiral allowed than is necessary to keep the bullets in the grooves.

3. The most perfect facility of loading.

4. The expansion into the grooves, so ensuring the necessary rotation, is effected at the instant of the inflammation of the charge of powder, in consequence of the upsetting of the lead, assisted possibly by the wood plug which closes the orifice at the base of the bullet, but which no doubt prevents any collapsing of the sides of the bullet when leaving the barrel, a circumstance which would otherwise happen, and thus disfigure the shape, and act prejudicially in other respects. The advantages on the side of the plug are, besides the above, the less frequent fouling of the barrel; in fact the grooves are cleaned out and lubricated after every shot.

5. The calibre of the arm ·577 allowing of a bullet of sufficient weight to do all that is required of it, but not so heavy as to prevent 60 rounds being carried well by the soldier.

6. The shooting of this arm as a line infantry weapon is most superior, and when carefully made throughout corresponds to every requirement of the best-instructed infantry soldier.

7. At long ranges, that is to say, up to 1,000 yards, though only sighted to 900, the arm makes very good practice, and thus becomes qualified for a rifle-arm for special corps.

If to all this is added that the arm was one easy to be made, and that the ammunition was of a form capable of being turned out in large quantities very rapidly, it would appear that the Committee had not been far out in their judgment or sagacity in the selection of such a weapon.

The above points, many of which concern the manufacture of the arm, were of vital importance at a period when it was of

the utmost consequence to obtain a rapid supply, for had any complexity, either in the form of barrel or bullet, interfered much with the manufacture, it would have been almost impossible to have armed all our troops with it during the late war.

I have now sketched so far the history of the rifle down to the present moment, and in so doing it is only necessary to bear in mind—first, that the principle upon which correct rifle practice depends is the insuring a rapid rotatory motion of the longer axis of the cylindro-conoidal bullet in the direction of the plane of fire—thus equalising the resistances all round the pole of its circular motion; and, secondly, that the system adopted to ensure this result was one including the greatest facility in loading, and thus rendering the arm well-adapted for the line infantry soldier.

Whether greater accuracy may not yet be obtained by some alteration in the form of rifling, or shape of bullet, or structure of interior of the barrel, and without interfering with ease of loading, and all the other advantages named above, is not for me to determine. Everything, to a certain limit, is possible; and it is not to be supposed that the best arm, combining every advantage, has yet been constructed. One thing must, however, be considered as reducing the question down to rather narrower limits than at first sight may appear when the rifle is viewed abstractedly. I allude to the class of men into whose hands the arm is placed.

There is no difficulty, comparatively speaking, in the instruction of an individual ; but here we deal with the mass, and have to contemplate the intelligence of the body, and to ensure that our standard of perfection or of instruction is not of a nature too high to be hoped for from the many.

Disturbing influences, error of judgment, physical defects, and other causes, all enter largely into the question of the real value to be anticipated from pursuing the question of greater perfection of fire-arm while the soldier remains stationary at a certain point.

Take for example the difficult task of instructing in judging distances even upon easy ground, and the constant practice required even to obtain a tolerably good judgment on this point. Then, transfer yourself, in imagination, to a country of an undulating nature, broken and interspersed with wood and water—a man not

only looking out to shoot at, but to be shot at, hurrying as well as his adversary from one position to another, and excited by every circumstance which in battle may be considered to operate so powerfully to disturb a man's judgment or his aim.

Why, in this mere matter of judging distances, a man who can judge better than another will, with a weapon much inferior to the other, probably do more execution.

In point of fact, the difference in degree of accuracy at ordinary distances of two rifled arms, bears no proportion whatever to the difference which exists in the capability of appreciating distances between any two individuals.

Again, it must be borne in mind that the larger the body which has to be instructed the more difficult becomes the task of raising it up to a certain standard, and generally speaking, the lower, comparatively speaking, must that standard be.

In the instruction of a rifle corps *per se*, a high standard could, no doubt, be aimed at, and possibly attained.

No rifleman should fire quickly; every one of his shots should tell; and he may more frequently be called upon to fire against skirmishers, or artillery and cavalry in extended order, and therefore he should be calm and deliberate; it is not so with the line infantry soldier, whose instruction should be based upon this fact, that his function is to fire quickly, and at, comparatively speaking, short distances.

It is far from my wish or inclination to decry the advantage of the greatest possible amount of accuracy in an arm which it can be made to possess. All I desire to enunciate here is, that there are many important conditions for a fire-arm to fulfil besides great accuracy, and that individual and other errors may entirely nullify the advantages to be anticipated from such an arm when placed in the hands of a line soldier.

Here, as in every other thing, the balance of advantages against disadvantages must be struck, and a mean term found which shall give the best results under every condition.

As a corollary to what has just been said, it would appear that if we regard infantry as still likely to be employed in two different capacities, viz., as the soldier of the line acting in mass, and as the

rifleman proper acting as *skirmisher*, or real light infantry man, two different degrees of instruction are demanded—

Firstly. That of the infantry soldier, for the proper employment of his weapon at those distances at which he is likely to use it: and

Secondly. That of the rifleman, who, from being called upon to act independently and in an individual capacity, and at distances greater than those of the line soldier, and perpetually varying, should have as far as possible a complete knowledge of his arm, and above all a facility to be obtained from long and continued practice of judging distances.

For the larger body who have to be instructed, a system combining the utmost simplicity and efficiency with the least demand upon the intelligence or memory of the soldier, seems the most likely to succeed.

For example, and in order to make my meaning clear, I suppose that the fire of infantry in line commences at 400 yards, which may be considered as the greatest distance at which file-firing should be allowed to take place.

It would simplify the operation of the soldier very much if a single sight could be formed, to be employed at all distances from 400 to 100 yards, without giving him the trouble of thinking about altering it for varying ranges. Again, it would be an additional boon if it could be found that this fixed sight, combined with aiming always at one and the same part of a man's body, would ensure his being struck at any distance between the 400 and 100 yards.

The only instruction, as far as distances were concerned, would then be restricted to the single one of 400 yards; and, as far as aiming would have to be taught, that of firing at the point determined upon.

Now this I believe to be quite feasible, and in fact, from my own experiments, I have ascertained that, by aiming at a determinate point, low down on a man's body, I could strike him by using one sight at any distance between 400 and 100 yards; of course the part struck being higher at the closer distance, but still some part of the body was struck.

I mention this, as no doubt it may gain the attention of those

who have the duty of instructors of musketry, and who have, before this, found out how difficult, nay, almost impossible, it is to teach men to judge distances with anything like sufficient accuracy; and, as I said before, that as the errors on this head are much greater than the relative accuracy of different arms, and are such which every one must recognise, it becomes a most important question, in order to prevent the useless expenditure of costly ammunition, to devise some method by which the soldier shall be relieved, to a great extent, of the call upon his judgment in this matter of distances. If so difficult to attain in peace time, how can we expect the efficient and correct exercise of this faculty in the field?

The instruction of special corps of riflemen, and also of the flank company of regiments of the line, might be more extended, and in fact every care bestowed upon these *sharpshooters*.

The flank companies of a regiment might be filled with the best marksmen of the regiment, and a proper spirit of emulation cultivated amongst the men to induce them to strive after such a distinction as promotion to a flank company.

And yet one more idea would I propound here, and one quite as necessary to be considered as the putting of the best arm into the soldier's hands, I allude to the preservation or maintenance of the arms.

Without the utmost caution, vigilance, and watchfulness on the part of all the officers and non-commissioned officers of a regiment, the arm may be soon rendered unfit to be considered as a good shooting one, by the inconsiderate and rough usage it meets with in the hands of the soldier. A rifle is a delicately constituted weapon, and, like a horse, soon shows the effect of *hard work*.

This is a point of great importance, in which the moderns may well learn a lesson from the ancients. Who more careful to keep his arms in good condition than the Roman legionary soldier? Where do we find in modern armies such attention paid to this essential point as in the code of the old Roman armies? With us instruction in the use of the arm should be also accompanied by the most stringent regulations, enforcing the utmost care to be taken of it, and prompt and severe punishment should follow any carelessness on this head.

As a manufacturer I have taken the liberty of enlarging upon these points. I wish to see the best arm in the hands of our men that can be obtained under the conditions required, and I wish to see that arm, at the end of ten years, shooting as well as when it was first issued.

Comparative Table of Various Arms.

WEIGHT OF DIFFERENT ARMS AND THEIR AMMUNITION.

	lbs.	oz.
1. Percussion Smooth Bore (·753), 1842, and bayonet .	11	3
Ammunition, 60 rounds and 75 caps . . .	6	10
Now obsolete.	17	13
2. Ditto, ditto rifled (·753) . . . about	11	0
Ammunition, 60 rounds	8	9
	19	9

Bullet, with cup, 848 grs.; diam. ·745 to ·746; charge, 3 drs.
Used by the Royal Marines.

	lbs.	oz.
3. Ditto, cut down for Naval Service (·753) . .	10	6
Ammunition, as No. 2	8	9
	18	15
4. Minié, ·702, Rifled Musket Pattern, 1851 . .	10	8¾
Ammunition, 60 rounds	7	0
	17	8¾

Bullet, with cup, 696 grs.; diam. ·690 to ·691; charge, 2½ drs.
Superseded by the 1853 pattern arm.

	lbs.	oz.
5. Enfield Rifle Musket, ·577, pattern 1853 . .	9	6
Ammunition, 60 rounds	5	8
	14	14

Bullet, 530 grs.; diam. ·568; charge, 2½ drs.

	lbs.	oz.
Short Rifle, pattern 1855, sword bayonet . . .	9	11¾
Ammunition, 60 rounds	5	8
	15	3¾

Bullet as for Enfield rifle.

For Rifle Regiments, Serjeants of Infantry, and Marine Artillery.

Short Rifle for Serjeants of Infantry and Royal Navy, E.I.C. as above; only ordinary bayonet and brass mountings.

Artillery Carbine and Sword Bayonet, ·577 bore .	8	3¼
20 rounds	1	13
	10	0¼

Charge, 2 drs.

Sapper's Carbine, oval bore	9	2

Ammunition as for Enfield.

Calibre ·577 minor axis, ·589 major „ } muzzle. Calibre ·580 minor, ·592 major } breech.

Increasing spiral from breech to muzzle one-fourth of revolution.

Brunswick Rifle, 1836, weight of, with sword bayonet .	11	15
Ammunition, 60 rounds	7	6
	19	5

Having now discussed the first portion of the subject, I come to that part which touches upon the *future* of the arm, in relation to its probable influence on modern warfare.

This subject is one which least of all will bear to be treated dogmatically. I come to it with considerable diffidence, and own that in the matter of a mere opinion I am not more likely to form a correct, or as correct a one as many an officer who has also carefully studied the art of war. At the same time I do not shrink from drawing out discussion upon this interesting point, and more particularly as it will lead one off the more abstract question of rifle practice, &c., into the larger one of tactics generally, including, of course, in that term manœuvres of infantry.

I have not considered it necessary to introduce strategy as likely

to be directly affected by the introduction of the rifle, except in so far as a better armed and better instructed army, and one with its commissariat and whole interior economy better managed, than those of its adversary, may give greater confidence to the general commanding, in arranging the lines of operations, objective points, and in short the whole plan of a campaign.

Still, the general principles of strategy must remain the same; they depend upon circumstances and causes which are fixed and immoveable, and such as the military topographer will at once recognise.

These causes will ever govern the lines of operations, the retreats of armies, and the defence of certain points.

For example, in examining the map of Europe, or what is better that of France, and that portion of Germany which is included in the campaign of 1796, by the Archduke Charles (or that portion of France entered by the allies under Schwarzenberg by Basle, opposite *Belfort)*, or the southern frontier, and its roads concentrating on that town which is the centre of defence for that region, viz., Toulouse ; or the northern frontier, extending from Dunkirk to Lauterbourg on the Rhine, and defended by five or six lines of fortresses culminating in Paris ; all these will convince the military reader that the operations of armies will continue to be governed by the same rules which have raised this branch of the art of war into a science.

As a digression, I cannot do better than impress upon every young officer the value in every sense of studying military topography. The advantages to be gained by any one from accustoming himself to study not only the relations of sieges and battles, but the causes which have operated (even from the times of antiquity) in determining more than once battles to be fought in certain localities, operations to be conducted on certain lines, and the occupation of certain points to be always attended with favourable results, will more than repay the labour bestowed upon the subject, besides giving him a fund of interesting information, to be made use of as a tourist or scientific traveller.

I cannot afford time to enumerate localities, or enter into details here, but I will mention a valuable little work on military topography,

that by M. Lavallée of the French service, and a portion of it, viz. that relating to the Military Topography of Continental Europe, translated by Col. Jackson.

The study of military topography leads to the study of fortified places, and of fortifications in general. The great extension of the principle of entrenched camps, with their peculiar sites, is of great interest to the military man. I recommend, as particularly worthy of note, the fortifications of Antwerp (improved of late), Diest, Rastadt in Baden, and Ulm, &c., all of recent date, and each illustrating some particular ideas, and fulfilling particular objects.

All these places are likewise interesting, as furnishing subjects of thought for those who contemplate the value of the rifleman in the siege and defence of places.

Questions as to the proper length of lines of defence—the value of the caponière, or casemated system of Montalembert, illustrated by so many Prussian models, the examples of *active* defences of places, with the last and most splendid of all, that of Sevastopol, may all contribute towards the solution of the question,—"What influence will the extended employment of riflemen exert in sieges?"

What, however, are to be the tactics of modern infantry and the relation of the other arms to them?

The infantry is the most perfect element of an army, and has always been recognised as such.

The offensive and defensive characters have always pertained to it, and to it alone.

Artillery possesses only the defensive character, and cavalry the offensive; consequently, it has always required a proper union of horse artillery and cavalry to give the single perfect element required in a military body. Either of these two arms becomes the complement to the other.

It is therefore to be expected that infantry should seek to perfect themselves in their arms and general mobility; and it is no disgrace in the other two arms to have to follow, and keep up, if possible, with its progress in those particulars. It would be unfortunate if anything should tend to disturb the proper relationship that ought to exist between the three arms.

Formerly, when the Swiss infantry or the Spanish infantry had a preponderating force in the decision of battles, the true action of cavalry was lost sight of. Vain attempts were made to pierce these solid masses of infantry armed with long pikes; the results of battles were not so decisive as they ought to have been, and the true principles of the art of war were lost sight of.

The introduction of artillery into the field tended to re-establish the balance between the three arms.

The unwieldy masses of infantry presented most favourable targets for the new fire-arms; and, when once broken, the action of cavalry was properly employed in completing their defeat, and preventing their again rallying. From this cause may be traced the gradual giving up of the deep column formation and the extended occupation of ground by thin long lines.

The deep formation was not given up at once, in consequence of the want of skill in manœuvring of the three arms; and it was only finally effected when the infantry had been armed with a fire-arm possessing an offensive, as well as a defensive, character; or, when the infantry, armed with a musket and bayonet, had all the force of the old infantry armed with the pike and musket.

To remedy the weakness inherent in so extended a disposition, science came in to assist in the selection of ground, in the determination of the method of attack, and the points of attack; and gradually the art of war emerged from the obscurity under which it laboured in the middle ages, and shows itself now in the proper and beautiful proportions of an art, or even of a science.

I have, in a former part of my lecture, assumed that infantry will still be composed of the line-infantry soldier proper, and of the special corps named riflemen.

I do not think that under any circumstances battles could be fought or gained by skirmishers or infantry acting in extended order. The impossibility of controlling or directing such irregulars would nullify all advantage likely to be obtained from each man being a good marksman. Independent of which, such a system would fall to pieces in the end from its own inherent defects. An army would cease to act as a whole, and operations would be restricted to a multiplicity of small and insignificant attacks at isolated points.

Well, then, we come to the present system, viz., the action of infantry in a mass, and that of skirmishers, which I believe cannot be disturbed by the introduction of the rifle.

The true force of infantry in action consists, first, in its fire ; and, secondly, in the charge.

These two cannot be separated. No good or decisive results can be anticipated on land or at sea by playing at "long bowls." That infantry or that vessel of war which shrinks not from opening fire against an adversary at ranges of about 400 yards and under, and delivers its fire with the greatest efficiency, coolness, and determination, will come off best. The distance is then favourable to close; and if rapid and decisive results are to be aimed at in future wars, they will only be attained by using the superior arm which our soldiers now possess, at distances not materially varying from those at which they formerly attempted with inefficient means to do their duty.

Modifications in point of celerity of movement and simplicity in bringing up men under fire, or to take up certain positions, will materially influence the results. It is possibly now the time for endeavouring to remodel the old Prussian system of manœuvres.

What did the Duke of Wellington mean when he said, after witnessing a review of the Prussian army, that he thought, with his little army, he could manœuvre round them before they had made a change of position? Was he not alive to the necessity of rapid movements, or rather movements which become so from being simple and easy of execution?

Much has to be done, I believe, in this respect, without at the same time attempting to move bodies of men at the rapid pace advocated by some French officers of the present day. The direction which every ones energies should take is that of simplifying the present manœuvres of the battalion to the utmost, and the quick and true formation of the line which naturally is the final object of every change of position.

With respect to squares, it is a delicate matter to express an opinion upon. I would, however, point to the famous battle of Minden, in the Seven Years War, where the finest and best appointed cavalry in Europe was utterly routed by the English Con-

tingent acting in line. In fact, the English regiments advanced in line against the French cavalry, who were posted in front of them, and although charged repeatedly and attacked by artillery on the flanks of the cavalry, this infantry received and defeated the cavalry, in line, and no doubt in a much more signal manner than if they had been formed in square. With the rifle, at present, I should prefer meeting any cavalry in a line formation to that of a square, the extent of fire developed would do all the necessary work, and I consider that no cavalry could face such a fire. The reason why cavalry have not hitherto done much against squares, is from the difficulty of bringing a cavalry soldier up to the square, and not from the real strength which such a formation gives the infantry.

These are, however, points on which many different opinions will be held; but the action of the rifle will, I think, determine many waverers.

With respect to the action of the new arm as determining a corresponding improvement in the arms of both artillery and cavalry, it must be at once acknowledged that the action of skirmishers firing at 800 or 900 yards, and possibly with explosive shells, against masses of artillery or cavalry, would be very inconvenient and uncomfortable to these arms.

The improvement in artillery will, it is believed, to a considerable extent, balance affairs as far as this arm is concerned, and the artillery officer must, by tactical skill in the position of his guns, prevent their being made the object of an attack by skirmishers. Artillery not being intended to act, except against *masses*, there is no reason for supposing that as long as the preliminary action of skirmishers against skirmishers is going on, the guns would be posted in such a way as to attract or draw upon themselves this fire.

The artillery officer will no doubt be more on the alert than ever, to avoid posting his guns too soon or in too exposed a situation, but when once in action the great effects produced by the late improvements in shell and spherical case shot, together with the great facility an *artilleryman has of ascertaining his distances*, from being able to *watch and witness the effects of his shot*, will most certainly give to this arm a great preponderance in determining future battles.

The true action of cavalry, as operating against infantry, will be restricted, doubtless, to its legitimate object. We shall not see again cavalry thrown away at an early period of action, while infantry are still intact. The arm must be still more than ever retained as a special reserve for determining the rout of infantry when in disorder from the action of artillery or other causes, and for reaping all the fruits of a victory by pursuing and destroying a broken army.

The action of cavalry then would seem to be both simple and proper, both as regards its real functions, and in view of the impossibility of its standing before compact infantry armed with the rifle. The special employment of any corps of cavalry in the capacity of the old dragoons, viz., by arming them with rifled arms, and employing them mostly to use their arms on foot, and in skirmishing order, is a subject which I do not enter into. Artillery might no doubt receive very efficient protection from such a force, but it is probable that a still better protection for the flanks of artillery, always very weak points, would be some special infantry corps whose duty would be to keep off skirmishers from approaching too closely.

In the attack and defence of places I look for important changes as likely to arise from the employment of the rifle. Where an army is numerous in a besieged place, and can afford, in consequence, to act, as Carnôt suggested, in an *active sense*, then will sieges be far different things to what they have hitherto been.

The defence of the enceinte will not require to be entrusted to works as closely allied to the body of the place as at present. The length of lines of defence, at present restricted to the powers of the old musket, will be taken into consideration in the projection of any new fortifications, and possibly greater alterations in this respect will result than I have anticipated in the art of tactically disposing of or engaging troops in the open field.

I must fairly own that many different opinions to those I have stated are held by foreign military writers upon the subject of the probable alteration in the system of infantry tactics as necessitated by the introduction extensively of the rifle.

The question by them is regarded in two lights, according to the

different views held: first, as a complete transformation of the infantry soldier into a rifleman proper, and the very great or almost exclusive action of skirmishers in future warfare; or by others the creation of the flank company of all regiments into riflemen, while the centre company are armed either with the smooth bore or rifle sighted for short distances, and the drill so altered as to allow of movements being rendered much more simple, and their execution quicker, by the adoption of the *pas gymnastique*.

The former is advocated in a work upon small arms, written by a Belgian officer.* He says, at page 334:

"Rifled arms giving the advantage of accuracy at very long ranges, the fire of infantry ought to become, in a greater degree than ever, a fire of skirmishers, and, their fire assuming much more importance than formerly, the extent of front presented by armies must necessarily be much increased."

He intends, I imagine, not that the infantry soldier should be allowed to skirmish after the manner of the present light infantry or rifleman, but that greater space than that occupied at present by men in line should be allowed, in order to give greater independence to the individual soldier. How this is to consist with the solidity so necessary for the masses of infantry to have, when required suddenly to charge, or to concentrate their fire upon masses of cavalry, or the enemy's troops assaulting a position, I am at a loss to say. The difficulty in restraining men from uselessly firing away ammunition at long distances, either on the supposition that they are doing good or from the mere force of example, would render the above system a hazardous one to adopt against an enterprising army looking out to close at a convenient opportunity.

The writer continues as follows:

"The effect of the new arm, and its great range giving greater confidence to the soldier, will allow of his doing more execution with it than with the old musket. At great distances he will adjust his sights instead of firing at random: close to the enemy he will fire with more *sangfroid* than formerly, since he will feel confidence in his arm.

* Captain Gillion, Belgian Artillery, 1856.

"It may be added also that the very occupation of thinking of and adjusting the sights for different ranges will take from him all thought of danger, and he will find himself in as favourable a position as the artilleryman, whose coolness and *sangfroid* are proverbial. . . . .

"Without doubt it may happen, sometimes, that such things as the smoke on the field of battle, dust, the necessary movements, or the moral situation of the soldier, will nullify the fruits of all special instruction, and will render illusory all the advantages from the superiority in the arm," &c. &c.

The writer, however, thinks that these latter circumstances are only exceptional, and that in all others, the soldier taking the necessary time required to make the best use of his arm, there will still be a very marked superiority over the old arm. This latter statement I entirely agree with; but the means proposed for obtaining the results are not such as I can see to be at all in accordance with the circumstances of any battle-field.

I cannot bring myself to believe or comprehend how it is possible to consider every line infantry soldier a marksman, and one who is to be allowed to be constantly altering and adjusting his sight. Battles have never yet been won through the independent action of the individual soldier. The action of the mass operating as a mass at the decisive and critical moment will still, I think, be required to produce the greatest results.

In the Belgian service a wiser regulation exists on this head than is advocated by the writer of the work from which my quotations have been made. For example—the infantry soldier, practically, employs only three sights for distances as far as 480 mètres.

The first is used from 0 to 300, by aiming at different parts of the body.

2nd. From 300 to 412.

3rd. From 412 to 430.

The *carabine à tige*, Belgian, is sighted to 900 mètres.

Only two sights are used up to 500 paces, or 375 m., and then by special sights for each additional distance up to 900.

Here there is an acknowledgment at once of the necessity of some simplicity in arranging the sights, although the soldier's

memory is still burdened with the recollection of various points to be aimed at.

I have before attempted to show that greater simplicity than even this is desirable, if not imperatively called for.

A French general-officer—Gen. de Lourmel—is the advocate of the second proposition; and as he went much into detail upon the subject, and was subjected to severe criticism at the time of his pamphlet appearing, I will enter a little into the opinions there propounded.

The general first of all praises very much the light-infantry or riflemen of the French army, called the Chasseurs-à-pied, and considers that the success which has attended their formation must lead to considerable modifications in the infantry of the line.

The alterations, then, in the instruction of line infantry are to be based upon that of the Chasseurs, and every attempt made to introduce very rapid movements in all changes of position or deployments, thus enabling them to follow artillery or even cavalry at a moderately quick pace, but retaining sufficient solidity to attack in line.

Some experiments of this nature were conducted by the 51st Regiment, in presence of the emperor, at Paris, the movements being executed by the three battalions at the different rates proposed, and it is said that the men did not show any symptoms of distress.

Undoubtedly, the system at first sight offers much which appears of great value, and no doubt, if practicable, would give immense advantages to an infantry thus handled.

There are, however, two points which must be considered. The value of infantry consists as much or to a greater extent in the accurate and rapid fire it can deliver than in rapidity of movement.

The disturbance to the whole physical system which must result from very rapid movements, when carrying a heavy load, is adverse to accurate shooting, and is altogether unfavourable to the proper employment of a rifle.

Again, the actual experience which the French have had in their Chasseurs, in respect of the injurious tendency which their peculiar

drill has upon the health of the men, is sufficient to show that with ordinary line infantry, where men are not selected with such care as for the Chasseurs, the rapidity of movement advocated by the general would drive half the officers and men out of the regiment.*

It is well known that the ranks of the Chasseurs have to be constantly weeded of those officers and men whose physical abilities are unequal, after a certain time, to the fatigues of this artificial system. In short, it would appear by all accounts, to lead to a wasteful expenditure of human energy.

Generally speaking, where the necessity for a sudden exercise of physical force is required for a short period, the demand upon the physical frame and constitution of the soldier trained in the ordinary way may be safely made, and has always been responded to. It is only between very limited periods of any man's life that a constant course of violent exercise may be considered as conducive to health and strength. After that period, the energies must be husbanded, in order that on a sudden demand for them they may be forthcoming.

Another and very material disadvantage in very rapid movements is the impossibility of preserving the cartridge from being injured in the soldier's pouch. To give a facilty in loading, the cartridge has been made of a certain texture and strength; but this is not sufficient to bear rough usage or shaking about in a cartouch-box.

I would here call attention to the medical opinion of a distinguished French practitioner, Dr. Champouillon, upon the subject of rapidity of movement when long continued, and its influence on the human frame:—

" The running pace is the severest trial to which a soldier can be submitted, and can only be borne by men of short stature and square broad frame. To submit men of weak physical formation to such a pace, as a rule, causes frightful ravages.

" It would be, therefore, on medical grounds, a deplorable circum-

* Pas accéléré—quick step—110 in a minute. Engl. 108 in a minute=3·07 miles an hour.
Pas ordinaire—ordinary pace—76 in a minute.
Pas gymnastique—the pace of *running*.

stance to apply the pas gymnastique, or running pace, generally to the line infantry soldier.

"More than once the medical officers of regiments of infantry, and even those of the Chasseurs-à-pied, notwithstanding the special selection of the men for these regiments, have felt it necessary to report to the General Medical Board, in the way of special reports, the serious evils resulting to the soldier from the employment of this trying pace, whether in their manœuvres or on fatigue duty.

"Some regiments having, in imitation of the Chasseurs, established the pas gymnastique for the performance of their fatigue duties, the serious illnesses which were brought on in consequence caused an order to be issued stopping the practice."

I have now completed in an imperfect manner the task I assigned to myself. I have touched upon the history, the theory, the employment, and the probable future of the arm, in its relation to modern tactics.

I think that I have reason on my side in insisting strongly upon the necessity for the utmost simplicity, combined with efficiency, in the instruction of the ordinary soldier, and of the value to be obtained from the more extended instruction of the special corps. I have shown where the difficulty in this instruction lies; and, that in foreign armies, an attempt to get too much out of the ordinary soldier, or even from the special corps, may end in failure. The mark may be overshot as well as not reached.

In our own service we have an excellent school of instruction at Hythe, and the circulation of officers of every regiment in the service through this school will prove most valuable as a means of instructing them in the powers of the new arm, and what it can do when under favourable circumstances. The ultimate point to which the line infantry soldier is to be instructed is, of course, not for me to lay down.

I would merely throw out as a subject for thought and consideration the various remarks I have made in this paper. I hold them only as matters of opinion. I may have underrated the mental capacities of the average line soldier; but, if so, I shall most willingly confess my error if it can be satisfactorily brought home to me.

As a mere brochure upon a very interesting topic for all military men, I offer it to the military public, and have to thank those present for their kindness in listening to one who had, from his numerous duties, hardly the necessary time to arrange his materials in a proper form for a public lecture.

July 3rd, 1857.

Colonel the Honourable JAMES LINDSAY in the Chair.

ON THE GENIUS AND CAMPAIGNS OF HANNIBAL.

By Lieut.-Col. MacDougall.

In the present lecture I propose to bring down the narrative of the Second Punic War only so far as to the end of the first campaign in Italy ; that is to say, to the battle of the Trebbia, which naturally terminates the first epoch of that contest.

The Second Punic War was termed by the historian Livy the most memorable of all wars that ever were carried on. And there is no exaggeration in the expression, for a parallel to its incidents and achievements, as well as to the great importance of its results, is only to be found in modern history. That great struggle was to determine whether the world was to be ruled by Rome or Carthage.

On this subject the French historian Michelet, in his "Histoire Romaine," has the following passage.

"It is not without reason that so universal and vivid a remembrance of the Punic wars has dwelt in the memories of men. They formed no mere struggle to determine the lot of two cities or two empires ; but it was a strife, on the event of which depended the fate of two races of mankind, whether the dominion of the world should belong to the Indo-Germanic or to the Semitic family of nations. Bear in mind, that the first of these comprises, besides the Indians and the Persians, the Greeks, the Romans, and the Germans. In

G A U L
Pyrenees
M E D I T E R R A N E
R. Iberus
Saguntum
Rhone
Massilia
Valence
R. Isara
Grenob
HAN

Map of part of
SPAIN, GAUL AND ITALY,
TO ILLUSTRATE
HANNIBAL'S MARCH FROM SAGUNTUM TO THE PO,
AND
HIS FIRST CAMPAIGN IN ITALY.

the other are ranked the Jews and the Arabs, the Phœnicians and the Carthaginians. On the one side is the genius of heroism, of art, and legislation; on the other is the spirit of industry, of commerce, and of navigation. The two opposite races have everywhere come into contact, everywhere into hostility. In the primitive history of Persia and Chaldæa, the heroes are perpetually engaged in combat with their industrious and perfidious neighbours. The struggle is renewed between the Phœnicians and the Greeks on every coast of the Mediterranean. The Greek supplants the Phœnician in all his factories, all his colonies in the East: soon will the Roman come and do likewise in the West. Alexander did far more against Tyre than Salmanæsar or Nebuchodonosor had done. Not content with crushing her, he took care that she never should survive: for he founded Alexandria as her substitute, and changed for ever the track of the commerce of the world. There remained Carthage—the great Carthage, and her mighty empire—mighty in a far different degree than Phœnicia's had been. Rome annihilated it. Then occurred that which has no parallel in history—an entire civilisation perished at one blow—vanished, like a falling star. The 'Periplus' of Hanno, a few coins, a score of lines in Plautus, and, lo, all that remains of the Carthaginian world!

"Many generations must needs pass away before the struggle between the two races could be renewed; and the Arabs, that formidable rear-guard of the Semitic world, dashed forth from their deserts. The conflict between the two races then became the conflict of two religions. Fortunate was it that those daring Saracenic cavaliers encountered in the East the impregnable walls of Constantinople, in the West the chivalrous valour of Charles Martel, and the sword of the Cid. The Crusades were the natural reprisals for the Arab invasions, and form the last epoch of that great struggle between the two principal families of the human race."

In the destruction of Carthage perished almost all the documents which would have conveyed to posterity a full idea of the character and institutions of Rome's great rival. But we can perceive how inferior Carthage was to her competitor in military spirit, military resources, and position; and how far less fitted than Rome she was to become the founder of a dominion destined to exist for ages,

which should bind together barbarians of every race and language into an organised empire, and fit them for becoming, after that empire should be dissolved, the free members of the commonwealth of Christian Europe.

One great source of the inferiority of Carthage was that she had no native army. Her citizens were essentially, that which the English have sometimes been taunted with being, a trading people.

Michelet remarks: "The life of an industrious merchant, of a Carthaginian, was too precious to be risked, as long as it was possible to substitute advantageously for it that of a barbarian from Spain or Gaul. Carthage knew, and could tell to a drachma, what the life of a man of each nation came to. A Greek was worth more than a Campanian, a Campanian worth more than a Gaul or a Spaniard. When once this tariff of blood was correctly made out, Carthage began a war as a mercantile speculation. She tried to make conquests in the hope of getting new mines to work, or to open fresh markets for her exports. In one venture she could afford to spend 50,000 mercenaries, in another rather more. If the returns were good, there was no regret felt for the capital that had been lavished in the investment : more money got more men, and all went on well."

And commenting on this, Professor Creasy, in his most interesting and valuable work on the "Decisive Battles of the World," has the following eloquent passage :—

"Armies composed of mercenaries have, in all ages, been as formidable to their employers as to the enemy against whom they were directed. We know of one occasion (between the first and second Punic wars) when Carthage was brought to the very brink of destruction by a revolt of her foreign troops. Other mutinies of the same kind must, from time to time, have occurred. Probably one of these was the cause of the comparative weakness of Carthage at the time of the Athenian expedition against Syracuse; so different from the energy with which she attacked Gelon half a century earlier, and Dionysius half a century later. And, even when we consider her armies with reference only to their efficiency in warfare, we perceive at once the inferiority of such bands of Condottieri

brought together without any common bond of origin, tactics or cause, to the legions of Rome, which at the time of the Punic wars were raised from the very flower of a hardy agricultural population, trained in the strictest discipline, habituated to victory, and animated by the most resolute patriotism. And this shows also the transcendancy of the genius of Hannibal, which could form such discordant materials into a compact, organised force, and inspire them with the spirit of patient discipline and loyalty to their chief, so that they were true to him in his adverse as well as in his prosperous fortunes. And throughout the chequered series of his campaigns no panic rout ever disgraced a division under his command, —no mutiny or even attempt at mutiny was ever known in his camp—and finally after fifteen years of Italian warfare his men followed their old leader to Zama, 'with no fear and little hope;' and there on that disastrous field stood firm around him his Old Guard till Scipio's Numidian allies came up on their flank, when at last surrounded and overpowered, the veteran battalion sealed their devotion to their general with their blood!"

Before entering on the relation of the Second Punic War, it will be well to give a short description of the armies of the two people who were engaged in it.

The general appearance of a Carthaginian army has been described by one of the historians of the period, as follows:

"It was an assemblage of the most opposite races of the human species, from the farthest parts of the globe. Hordes of half-naked Gauls were ranged next to companies of white-clothed Iberians, and savage Ligurians next to the far-travelled Nasomanes and Lotophagi. Carthaginians and Phœnici-Africans formed the centre; while innumerable troops of Numidian horsemen, taken from all the tribes of the desert, swarmed about on unsaddled horses and formed the wings; the van was composed of Balearic slingers; and a line of colossal elephants with their Ethiopian guides formed, as it were, a chain of moving fortresses before the whole army."

The Spaniards and Africans were armed with helmets and shields, and, for offensive weapons, with short cut-and-thrust swords. The Africans carried a spear in addition.

The Gauls carried long javelins and huge broadswords and

targets, similar to those described by Sir Walter Scott as having been the weapons of the Scottish Gael at a more recent period.

In the contest now under consideration, Hannibal's heavy infantry was composed of Spaniards, Africans, and Gauls ; his light infantry, of the famous and formidable Balearic slingers and Gaulish irregulars. The only cavalry we read of as having accompanied him into Italy consisted of Numidian Irregulars, who were yet very formidable in the field, and the best scouts in the world. But after his entrance into Italy Hannibal organised a body of Gaulish heavy cavalry, which did him good service in his subsequent campaigns.

Rome, the iron kingdom of prophecy, was the greatest military power the world has ever seen ; conquest was the breath of her nostrils ; and her military organisation was the most perfect that has ever existed. The following extract from Gibbon enables us to understand by what means the Roman dominion was extended over the whole of the known world:

"The Roman peasant, or mechanic, imbibed the useful prejudice that he received advancement in being permitted to enter the more dignified profession of arms, in which his rank and reputation would depend on his own valour; and that, although the prowess of a private soldier must often escape the notice of fame, his own behaviour might sometimes confer glory or disgrace on the company, the legion, or even the army, to whose honours he was associated. On his first entrance into the service, an oath was administered to him with every circumstance of solemnity. He promised never to desert his standard, to submit his own will to the commands of his leaders, and to sacrifice his life for the safety of the emperor and the empire. The attachment of the Roman troops to their standards was inspired by the united influence of religion and of honour. The golden eagle, which glittered in the front of the legion, was the object of their fondest devotion ; nor was it esteemed less impious than it was ignominious to abandon that sacred ensign in the hour of danger. These motives, which derived their strength from the imagination, were enforced by fears and hopes of a more substantial kind. Regular pay, occasional donatives, and a stated recompense after the appointed time of service, alleviated the hardships of the

military life, whilst, on the other hand, it was impossible for cowardice or disobedience to escape the severest punishment. The centurions were authorised to chastise with blows—the generals had a right to punish with death; and it was an inflexible maxim of Roman discipline that a good soldier should dread his officers far more than the enemy. From such laudable acts did the valour of the imperial troops receive a degree of firmness and docility unattainable by the impetuous and irregular passions of barbarians.

"And yet, so sensible were the Romans of the imperfection of valour without skill and practice, that, in their language, the name of an army was borrowed from the word which signified exercise. Military exercises were the important and unremitted object of their discipline. The recruits and young soldiers were constantly trained both in the morning and in the evening, nor was age or knowledge allowed to excuse the veterans from the daily repetition of what they had completely learnt. Large sheds were erected in the winter-quarters of the troops, that their useful labours might not receive any interruption from the most tempestuous weather; and it was carefully observed that the arms destined to this imitation of war should be of double the weight which was required in real action. It is not the purpose of this work to enter into any minute description of the Roman exercises. We shall only remark that they comprehend whatever could add strength to the body, activity to the limbs, or grace to the motions. The soldiers were diligently instructed to march, to run, to leap, to swim, to carry heavy burdens, to handle every species of arms that was used either for offence or for defence, either in distant engagement or in a closer onset; to form a variety of evolutions; and to move to the sound of flutes in the Pyrrhic or martial dance. In the midst of peace, the Roman troops familiarised themselves with the practice of war; and it is prettily remarked by an ancient historian who had fought against them, that the effusion of blood was the only circumstance which distinguished a field of battle from a field of exercise. It was the policy of the ablest generals, and even of the emperors themselves, to encourage these military studies by their presence and example; and we are informed that Hadrian as well as Trajan frequently condescended to instruct the inexperienced soldiers, to reward the

diligent, and sometimes to dispute with them the prize of superior strength or dexterity."

In our own day, and in our own country, we may congratulate ourselves in having at the head of the army a royal prince, who has given the strongest evidence of his disposition to encourage and even to enforce all necessary military studies and exercises; and as the British soldier is in nowise inferior to the Roman legionary in strength, courage, or devotion, there is little doubt that, although we are not a military people, if the earnestness and energy of the Commander-in-chief be only emulated by his officers, the English army will have no reason to dread a comparison with any force either of ancient or modern days.

The Roman legions during the Second Punic War differed from those with which Cæsar effected his conquests 150 years later. The constitution of the legions which fought against Hannibal was as follows:

The infantry amounted to about 5,000 men. They were formed in three lines, at the distance from each other of about 100 yards, with the light-armed troops in skirmishing order in front of the whole. The first line consisted of the Hastati numbering 1,600 men. The second line of the Principes of the same strength. These were armed in the same manner. Each soldier wore a breastplate or coat of mail, brazen greaves, and a brazen helmet with a lofty crest of scarlet or black feathers, and carried a large oblong shield. His offensive weapons were a short cut-and-thrust sword, like that used by the Spaniards, worn on the right thigh; and in his hand besides a light spear he grasped the formidable pilum. This weapon was a ponderous javelin nearly eight feet long, having a shaft of four feet and an iron head of nearly equal length; and, although very inferior to the musket, since it was capable of only one discharge, yet when it was launched by a strong and practised hand at the distance of ten or twelve paces, there was not any shield or breastplate that could sustain its shock.

The third line was composed of 600 veteran soldiers called Triarii, who carried the same equipment as the men of the two first lines, except that in place of the two javelins they bore a spear: they may be regarded as the reserve. The light-armed troops must

therefore have amounted to 1,200 men, in order to complete the legionary infantry.

Each line was drawn up in eight ranks, or eight deep. The men of each rank stood three feet apart, and there was an interval of three feet between the ranks; but the men of each rank, instead of covering those in front of them, covered the intervals, so that the legionary infantry was formed in what is called quincunx order, or precisely in that formation which would be taken by several ranks of our own men preparatory to performing the sword exercise. Niebuhr supposes that this order was adopted for the purpose of enabling the men of the front rank to be easily reinforced or relieved after they had hurled their pila by those of the remaining seven ranks in succession, so as to keep up a continual discharge of these weapons if required, or to enable the same change to be made when fighting with the sword, which was always drawn as soon as the pilum was discharged.

A small body of cavalry formed a component part of each legion; but it was always found necessary to raise independent bodies of cavalry to act with the Roman armies, the legionary horse, 300, being only sufficient for outpost and foraging duty.

Every Roman legion of the strength above described had in the field attached to it a legion of the Italian allies of the same strength and organization, so that we may always compute about 10,000 men, besides cavalry, for every Roman legion employed against an enemy.

I now turn to the relation of the events which immediately preceded, and which were the origin of, the Second Punic War.

Hannibal the son of Hamilcar, surnamed Barca or the thunderbolt, was with his father in Spain during the interval which elapsed between the First and Second Punic Wars; and he was only nine years old at the time when he took that famous oath of enmity against Rome which he so religiously kept in after-life.

Hamilcar commanded the Carthaginian armies in Spain with uninterrupted success for nine years. The expedition to that country was originally undertaken at his instance, because he foresaw that no long time could elapse before Rome and Carthage would again be enemies. He was sensible that Carthage was weak in consequence

of her having no native army; and he designed not only to train his existing army in a constant warfare against the bravest of barbarians, but to effect permanent conquests in Spain. It was his policy to attach the new subjects to the mother city by kind treatment, at the same time that he conciliated the native independent princes; and he hoped thus not only to ensure a constant supply of good soldiers to recruit his armies, but, by gaining possession of the productive gold and silver mines of the south of the Peninsula, to obtain the means of paying them.

Hamilcar was slain in battle in the year B.C. 229, it is supposed in the country between the Tagus and Douro rivers, to which he had pushed his conquests. Hasdrubal, his son-in-law, appears to have inherited not only his command, but also his spirit and genius. He consolidated the conquests of Hamilcar no less by his policy than by the influence of his personal manners and character; and he accommodated himself so successfully to the feelings and habits of the Spaniards which he had carefully studied with that view, that the native chiefs far and near vied with each other in their eagerness to become the allies of Carthage.

Rome watched the progress of Hasdrubal with uneasiness; and, as the threatening of a Gaulic invasion at that time rendered it inexpedient to have recourse to arms, she endeavoured to secure herself by a treaty, the provisions of which bound Hasdrubal not to push his conquests beyond the Iberus and obliged each of the contracting parties to abstain from molesting the allies of the other. The city of Saguntum had lately placed itself under the protection of Rome, and was therefore by the terms of the treaty secure from attack, although situated so far south of the Iberus. The Romans hoped doubtless by its means to obtain a more forward footing in Spain, from which, when the Gaulic war should be terminated, they might sap the newly-formed dominion of Carthage in that country.

Hasdrubal was assassinated in the year 221 B.C., after a successful administration of the affairs of Spain during eight years; and now Hannibal at the early age of 24, by the unanimous voice of the soldiers, was called to the chief command of the Carthaginian forces in Spain; and the Senate of Carthage ratified the choice of the army.

Two years were occupied with expeditions against the native tribes of the interior; but in the third year Hannibal, having matured his plans, resolved to provoke a war with Rome by besieging Saguntum. He accordingly laid siege to that city; and, although left entirely to its own resources by its covenanted protectors, it was no sooner taken after an heroic defence of eight months, than the Romans sent ambassadors to Carthage to demand that Hannibal and his principal officers should be delivered up to them for their infraction of the treaty.

In default of compliance with that demand the Second Punic War was declared, B.C. 218.

This short introduction has been necessary in order to convey a clear understanding of the progress of that great struggle; for it will be seen that the event was materially influenced by the operations in Spain at different periods of the contest.

Long before the declaration of war Hannibal had been maturing in his own mind his great project of the invasion of Italy, and had neglected no measure which could conduce to its success. He had sent emissaries through Gaul and across the Alps into Cisalpine Gaul, in order to sound the dispositions of the inhabitants along the route he proposed to follow, and to secure for his army a friendly reception from the Cisalpine Gauls on its descent from the Alps. He well knew the character of that lively and fickle people, and their hatred of the Romans, and he trusted to his own genius to convert their friendly feelings towards himself into active and faithful co-operation.

It was late in the month of May, B.C. 218, that Hannibal set out from New Carthage on his great undertaking; and, "thus," in the beautiful language of Arnold, "with no divided heart, and with an entire resignation of all personal and domestic enjoyments for ever, Hannibal went forth at the age of twenty-seven to do the work of his country's gods, and to redeem his early vow."

The force with which he quitted New Carthage amounted to 90,000 foot and 12,000 horse. He crossed the Iberus, and might have advanced without loss of time to the Pyrenees, but the country between the Iberus and those mountains was friendly to the Romans. Some of its towns held Roman garrisons; it therefore

became necessary to subdue this district entirely, and thereby to deprive the Romans of a convenient base of operations from which they might otherwise attack the Carthaginian conquests in Spain.

Hannibal effected this object speedily but at a terrible loss of life, and having left Hanno with 11,000 men to guard his new conquest and sent an equal number of his Spanish soldiers back to their homes, he crossed the Pyrenees and entered Gaul with an army, which was now reduced by these detachments, and the losses it had sustained in the field, to 50,000 foot and 9,000 horse.

From the Pyrenees to the Rhone his progress was easy, an unmolested passage through their territories being purchased by presents to the native chiefs. But the passage of the Rhone was not to be effected without opposition, for the city of Massilia (the modern Marseilles) was a fast ally of Rome, and its influence had been successfully exerted with the neighbouring tribes of the eastern bank to induce them to oppose the progress of the invader. Besides this, P. Scipio, one of the Roman consuls for the year, had lately arrived off the mouth of the Rhone with a fleet and army on his way to Spain; and learning there that the Carthaginian army had actually passed the Pyrenees, he disembarked his force, with the intention of opposing Hannibal on the Rhone and in the hope of preventing his advance beyond that river.

Hannibal, in his march through Gaul, kept his army as far as possible away from the sea-coast in order to conceal his movements from the Romans; and Scipio, hearing nothing of him and believing that his progress must necessarily be slow, lingered at the mouth of the Rhone at the very time when the friendly tribes of the eastern bank were vainly endeavouring to prevent Hannibal's passage of the river. Scipio contented himself with sending forth three hundred light cavalry to ascend the left bank of the Rhone, and to endeavour to gain some information of the movements of the invading army.

Hannibal is supposed to have struck the Rhone at a point about half-way between its mouth and its confluence with the Isara (the modern Isère). He immediately purchased all their boats and vessels of every kind from the inhabitants of the western shore; and, having constructed others of the timber which abounded on the spot, he in two days possessed sufficient transport to ferry his whole

army across the river. But he found the Gauls of the opposite shore assembled to oppose his passage, and his dispositions to effect it are well worthy of attention.

He sent off a strong detachment by night with native guides, to ascend the river for about twenty miles, and then to cross as best they could, where there would be no enemy to oppose them. This detachment selected a part of the river where its course was divided into two narrow channels by an island; and these effected the passage without difficulty by means of rafts constructed of timber which was found on the spot.

Hannibal, by previous concert, waited forty-eight hours from the time when the detachment left him; and then, on the third morning from that time, made all his preparations for the passage of his main body. The first division was assembled in the boats and only awaited the signal agreed upon to push off. That signal was the smoke of a great fire kindled by the detachment which had crossed the river, and which had now marched down to within a short distance of the barbarians on the opposite bank, whose whole attention was engrossed by the sight of Hannibal's preparations, and who crowded down to all the accessible parts of the river shore to oppose his landing. The first division now pushed off. The Rhone was full and rapid. The largest and heaviest vessels were placed highest up stream to serve as a breakwater to the others. The men pulled vigorously against the current, and, as the flotilla approached the opposite bank the attention of the Gauls was diverted to a mass of fire which appeared in their rear; and now the detachment which had kindled it charged upon their right flank and rear at the same time that the flotilla stranded, and the soldiers, at whose head was Hannibal, leaping ashore, attacked the bewildered barbarians in front. These made a feeble resistance and fled in confusion. The boats were instantly sent back for the second division, and before nightfall Hannibal's whole army, with the exception of the elephants, was encamped on the eastern bank of the Rhone.

Early next morning Hannibal sent out some Numidians to ascertain the position of Scipio's army. Not many hours elapsed before these horsemen were seen returning to the camp as if riding for their lives from a pursuing enemy. They had indeed fallen in

with the light cavalry sent out by Scipio, who had attacked and driven in the Numidians, and who now, as soon as they came in sight of the Carthaginian camp, wheeled about to carry back tidings to their general.

Scipio now no longer delayed to put his army in motion to oppose Hannibal, but he was already too late; for, when he reached the place which had been the site of the Carthaginian camp, he learnt that Hannibal had quitted it three days before, and had marched northwards up the Rhone. To have followed him through an unknown country, whose inhabitants as Gauls probably hated the Roman name, would have been madness; for it must be remembered that the tribes which opposed him on the Rhone were in the neighbourhood, and under the influence of Massilia.

Scipio therefore perceiving it was no longer possible to prevent Hannibal from reaching the Alps, resolved to meet him in Italy on his descent from those mountains, when he hoped that the Carthaginian army, exhausted by the fatigues and privations inseparable from such a march, and diminished in numbers, would be easily vanquished by the Roman forces which were already assembled in Cisalpine Gaul.

Scipio accordingly again descended the Rhone, and, having despatched his army to Spain under the command of Cnæus Scipio as his lieutenant, sailed himself to Pisa, whence he proceeded across the Apennines to take command of the Roman legions which were stationed on the Po under the prætors Manlius and Atilius, whose force amounted to about 25,000 men.

Meanwhile on the day after the sudden apparition of the Roman cavalry, Hannibal, having with some difficulty effected the passage of the elephants, broke up his camp and marched northwards, covering the rear of his line of march with his cavalry and elephants, for he believed Scipio to be in his immediate neighbourhood, and expected to be pursued.

The precise direction of his march is uncertain; but it appears probable that after having espoused the cause of one of two brothers near Valence, who contended for the chieftainship of their tribe, and having received from the successful competitor in return important succours in the shape of provisions, arms, clothing, and above all of

shoes—the Carthaginian army crossed the Isère—and, still proceeding for some distance up the left bank of the Rhone, at length struck off to the right across the plains of Dauphiné, and reached the first ascent of the Alps.

This was near the northern extremity of that ridge of limestone mountains which, rising suddenly out of the plains to a height of 5,000 feet, fills up the space between the Rhone at Belley and the Isère below Grenoble, and separates the plains of Dauphiné from the rich and wide valley extending from the Lake of Bourget to the Isère at Montmeillan. At the place where Hannibal crossed this ridge it is of no great width. His progress was opposed by the natives who guarded the defiles through which he must pass; but learning that these only guarded them during the day, and at night withdrew to their homes in the valley beyond, he seized the defiles after nightfall, and on the next day effected the passage of his army, not without being attacked however, and penetrated into the valley of Montmeillan. This town he took by storm. It was the principal stronghold of the barbarians, and in it he found large supplies of provisions and cattle.

Halting there for one day to rest his men, he then proceeded for three days up the right bank of the Isère. He was now met by a deputation of the natives who professed to be friendly, and having received from them supplies and hostages for their good behaviour, he was induced by their plausible conduct to accept of their guidance through a difficult part of the mountains to which he was approaching. Here he narrowly escaped destruction from an attack made upon him by his treacherous friends at the most difficult part of the way; but at length all obstacles were surmounted, and on the ninth day after quitting the plains of Dauphiné, Hannibal and his army stood on the summit of the central ridge of the Alps, supposed to be the summit of the little St. Bernard Pass.

The period of the year was about the end of October—the first winter snows had already fallen—and the climate of the country being far more severe than at present owing to the dense forests which at that time covered the face of Germany, Hannibal's southern soldiers must have been in dreary quarters. It is probable

that great numbers perished from cold, and certain that all must have been much worn and disheartened, for many mountain peaks still rose between them and Italy, through which their descent was likely to be both perilous and painful. But Hannibal's ascendancy over his men was complete, and after a rest of two days he resumed his march.

No more open hostility was manifested by the natives, but the natural difficulties of the route were greater than ever. The snow concealed the track, so that many losing it fell over frightful precipices. At last the army came to a place where the track had been carried away by an avalanche for a distance of 300 yards. It was impossible to turn this obstacle by scaling the heights above on account of the great depth of snow, and nothing remained but to reconstruct the road.

A summit of some extent was found and cleared of snow, on which the army encamped, and all working for their lives, succeeded in completing in one day a practicable road for the cavalry and baggage animals, which were immediately sent on to encamp in a valley beyond; but for the passage of the elephants a wider and more solid way was required, and its construction occupied two days more, during which both men and elephants suffered terribly from cold and want.

At length all passed safely, and after a further toilsome march of three days, the army cleared the mountains and entered the territory of the Insubrian Gauls, messengers from whom had previously met Hannibal on the Rhone to assure him of a friendly reception in their country.

The valley by which Hannibal is supposed to have descended into Italy is the Dorea Baltea, the same by which Napoleon penetrated with his famous army of reserve in the Marengo campaign.

The principal difficulties of this march arose from the lateness of the season. Had the summit of the Little St. Bernard been reached a month earlier, no fresh snow would have fallen and fodder might have been procured for the cattle without difficulty. The commissariat labours must have been very great, as provisions had to be carried for about 30,000 men and 8,000 cavalry horses; besides

what was required for the baggage and pack animals, which could not have numbered less than 5,000 or 6,000.

Hannibal carried with him out of the mountains only 12,000 African and 8,000 Spanish infantry, the remnant of 50,000 with which he quitted Spain. His cavalry too had dwindled from 9,000 to 6,000 horses.

He gave his army the rest its exhausted condition required, and, having recruited its strength, his first expedition was undertaken against the Taurinians of Liguria who were hostile to the Insubrians, and would not, on that account, listen to the proposals of Hannibal to join him against the Romans. He took and sacked their chief city, Augusta (the same as modern Turin), and struck such terror into the neighbouring tribes that they submitted and became his allies.

It is now time to turn our attention to the preparations the Romans had been making in the interval between Hannibal's departure from Spain and his arrival in Italy, and to the forces they had assembled to oppose their great enemy.

The two Consuls of the year were P. Scipio and Ti. Sempronius. Scipio's province was Spain, and it has been already related how, after his unsuccessful endeavour to stop Hannibal on the Rhone, he despatched his army to that province while he himself went to command on the Po.

Sempronius, with another consular army, was destined to cross over into Sicily, and thence, if circumstances were favourable, to make a descent on Africa, in the hope by threatening Carthage to recall Hannibal to its defence. But Hannibal had not neglected among his other preparations to provide against such a contingency. Before he quitted Spain fresh troops were at his suggestion sent to that country from Africa, to be commanded during his absence by his brother Hasdrubal, while he sent Spanish soldiers to defend the territory of Carthage, in order that the soldiers of each nation being quartered among foreigners, should be deprived of the temptation or opportunity to revolt.

He was also in all probability actuated by the consideration that his bitterest enemies were to be found in that faction of his fellow-citizens which was headed by Hanno. And he was therefore not

sorry to hold that faction in check by the presence of a force which, on account of its personal attachment to himself, owed an allegiance to Hannibal rather than to Carthage.

A third army consisting like the two first of two Roman legions, and the usual proportion of allies, and amounting to about 20,000 men, was sent to Cisalpine Gaul under the Prætor L. Manlius; and in order further to restrain the disaffected Gauls the military colonists of two Roman colonies to the number of 12,000 men, were despatched to occupy the important posts of Placentia and Cremona, on opposite sides of the Po. Thus the Roman force which was actually assembled in Cisalpine Gaul so early as the end of May of the year 218, amounted to 32,000 men, and was considered amply sufficient to preserve tranquillity. But, before Scipio had set out from Rome to assume his consular command, news arrived that the Boian and Insubrian Gauls had risen, that they had defeated Manlius and blockaded him in one of his towns, and that they had, moreover, dispersed the colonists of Placentia and Cremona, and driven them to take refuge in Mutina, another Roman colony on the road between Placentia and Ariminum.

One of Scipio's legions was immediately sent off under another prætor Caius Atilius, to relieve and reinforce Manlius, while Scipio's army was raised to its original strength by new levies.

Thus when Scipio arrived in Cisalpine Gaul towards the end of the year, he found the army of the prætors in the field, amounting to about 25,000 men, and the military colonists re-established in Placentia and Cremona; and it was of this aggregate force that he took the command.

It was now the middle of December, and unusually late for military operations; but Scipio, being anxious by a rapid advance to prevent a general rising of the Gauls in favour of Hannibal, crossed the Po at Placentia and marched up its northern bank; while Hannibal on the other hand knowing well that the Gauls were prevented from joining him by fear alone, and certain that his first success against the Roman arms would draw multitudes to his standard, descended the northern bank to meet Scipio, who, having crossed the Ticinus by a bridge he had constructed, continued to advance westward with the river on his left.

Thus was brought on accidentally a cavalry action, which has been magnified by the name of the battle of the Ticinus, in which the Numidians supported by the Gaulish heavy cavalry completely defeated the Roman horse, and in which Scipio himself was dangerously wounded. Here was first established the superiority of the cavalry of Hannibal over that of the Romans, to which he owed much of his subsequent success; and the country being level and open, and peculiarly favourable to the action of that arm in which they were so evidently inferior, the Romans retired behind the Ticinus over the bridge which they had made, and which they now broke down behind them; but this operation was attended with so much confusion that 600 men were left on the wrong side of the river and fell into the hands of the enemy.

Hannibal, not judging it prudent to attempt the passage of such a river as the Ticinus in the face of the Romans, retraced his steps up the northern bank of the Po until he found a convenient place, where he transported his army to the southern bank by means of the river boats. The Romans, now fearing to be turned, and lest Hannibal should reach Placentia before them, retreated in all haste on that city, and encamped under its walls.

Hannibal marching down the Po came in sight of the Roman camp two days after crossing the river, and, after vainly endeavouring to provoke the enemy to an engagement, he placed his army about five miles to the south-east of Placentia, cutting off Scipio's communication with Ariminum and Rome. Hannibal was here in a friendly country, for, as he expected would be the case, he was received with open arms by the natives on the south of the Po, and indeed the Romans had no hold on the territory of Cisalpine Gaul but by their garrisons or colonies.

Hannibal's appearance in Italy took the Roman Senate by surprise. They judged that the difficulties of the march must delay his arrival until the following spring. But they no sooner received intelligence that he was actually in Italy, than they sent for Sempronius and his army from Sicily, and despatched them to reinforce Scipio on the Po.

Sempronius was with his army at Lilybæum the furthest point of Sicily, when he received his orders, and it may give a small

idea of the immensely increased facilities which science has imparted to military operations, that—rather than encounter the dangers of a winter navigation of the Adriatic—instead of embarking at Lilybæum and sailing to Pisa—the troops marched through Sicily to Messana, there crossed the straits, and proceeded through the whole length of Italy by Ariminum to the scene of conflict on the Po, which they reached in about forty days. In our time the operation would have been effected in four, including the march from Pisa across the Apennines.

Sempronius effected his junction with Scipio unimpeded by Hannibal, and the army of the consuls then moving westward crossed to the left bank of the Trebbia, where it encamped. This movement was probably effected by the Romans in order to draw near the magazines, of which they possessed several, south of the Po; and on which they depended for their subsistence; for, as it has been already remarked, they had no hold on the country excepting by their garrisons, and without these the Roman army might have starved, while Hannibal had all his wants amply supplied by the good will of the inhabitants.

The army of the consuls amounted to about 40,000; and that of Hannibal had been so reinforced by the accession of the Gauls since its descent from the Alps, that it was little, if at all, inferior in numbers. It was Hannibal's policy to bring on a decisive battle as soon as possible. It is true the Gauls were friendly and furnished all his wants; but they were proverbially fickle; they were impatient to share in the plunder of Roman territory, and they would naturally chafe at a delay, the effect of which was to throw the burden of supporting the Carthaginian army exclusively upon them.

To force the Romans to a battle Hannibal attacked their magazines. One of the principal of these, Clastidium, was betrayed into his hands by the treachery of its Governor, and in it he found large supplies of corn. After this the Carthaginian army encamped on the right bank of the Trebbia, opposite to and within sight of the Roman camp. As Scipio was still disabled by his wound received at the Ticinus, the sole command of the Roman army devolved on Sempronius, who was no less eager to fight than Hannibal; and he

is not to be censured for rashness in desiring to bring on an engagement—for the hostile armies were equal in strength, and Hannibal's transcendant genius was as yet unproved—but for the entire disregard of all military rules he evinced in conducting the operation.

Early in the morning, Hannibal, having encamped his army on the opposite bank of the Trebbia within sight of the Romans, sent his Numidians across the river to skirmish with the Roman horse, and, if possible, to entice the Romans by retreating to cross the river in pursuit. He had previously posted his brother Mago with 2,000 picked men in an ambush in the overgrown bed of a watercourse, in such a position that when passed by the Romans in their advance after crossing the river, Mago might burst out upon their flank and rear while Hannibal engaged them in front.

Sempronius fell into the snare ; he ordered first his cavalry, and then his whole army, to follow the flying Numidians across the river. It was mid-winter, bitterly cold, and the stream ran breast-high. It is said the Romans had not broken their fast ; and thus wet, exhausted, and half frozen, Sempronius after crossing formed his troops in order of battle with the river in their rear.

Meanwhile Hannibal's men had breakfasted, and formed leisurely to meet the enemy's attack.

The Romans as was their custom were formed in three lines, with the cavalry, only 4,000 strong, on the flanks, in the order which has been described in the introductory remarks.

Hannibal drew up his army in two lines. In the first were his light troops and Balearic slingers ; the second line was composed of his heavy-armed African, Spanish, and Gaulish infantry, amounting to about 20,000 men.

The elephants, and the cavalry 10,000 strong, were divided between the wings.

The battle was opened as usual by the light troops, and the Roman Velites, already exhausted with their morning work, were soon driven through the intervals of the maniples to the rear. The Roman cavalry too, charged by the elephants and by the greatly superior hostile cavalry, was broken immediately and driven off the field. But when the Roman infantry came to close their courage and discipline seemed capable of restoring the balance ; but

at this critical moment Mago's ambush burst on their rear, while the Carthaginian cavalry charged both their flanks, and Hannibal pressed them in front. No troops could withstand such an onset. The centre legions indeed, overbearing all opposition, burst through their opponents and marched clear off the field to Placentia, but the remainder were driven back into the Trebbia with tremendous slaughter.

Only a small remnant reached the opposite bank; and Scipio after nightfall leading this remnant once more across the river, passed the enemy in the dark and joined his colleague within the walls of Placentia.

Thus ended Hannibal's first compaign in Italy; and I propose to conclude this Lecture with a few critical remarks on the events which have just been related.

REMARKS.

1. Hannibal's sagacity is evidenced by his resolution to provoke a war with Rome. He was well aware of the moral force which attaches generally to the initiative in war; and he perceived also that the relative circumstances of the two powers lent a particular value to the initiative in the present instance. In the First Punic War all the success had been on the side of the Romans, and the tide of fortune had set in too strongly in their favour to admit of its being turned by the genius of Hamilcar, who was advanced to the command of the Carthaginian armies too late for that purpose. In consequence of their successes in that war, Hannibal calculated that the Romans, reposing in a haughty security, would be very slow to believe that their despised enemies would willingly engage with them in a second struggle. Hence the Roman apathy in permitting Saguntum to fall without any more active attempt at its relief than the remonstrance of an envoy. Hence also the time that was lost to Rome, and gained by Hannibal for his preparations, in sending ambassadors to Carthage to demand an explanation after the fall of Saguntum, in place of immediately declaring war and accompanying that declaration with an invasion of Africa, for which purpose Sicily would have served as a convenient stepping-stone and base of operations.

Such an energetic proceeding on the part of Rome would have occasioned the recall of all the Carthaginian forces from Spain, and the consequent loss of all the fruits of the Carthaginian conquests in that country ; and Carthage would have commenced the war much in the same relative position as that which she occupied at the beginning of the first Punic war.

On the other hand if the Carthaginians took the initiative all the advantages would be for them. Hannibal calculated that, if he could once cross the Alps with an army, he could so work upon the hatred to Rome which was the universal feeling among the Cisalpine Gauls, as to convert that fickle people into zealous allies, and their territory into a base for his subsequent operations ; he hoped also to derive advantage from the constitution of the different states of Italy which were in alliance with, and dependent on, the Roman Republic. Though called by the name of allies they were in reality subjects ; and, although the existing generation in those states had grown up in peace with the Romans, their constrained alliance had not quite extinguished the old feelings of hatred and rivalry.

Hannibal counted on the influence of those feelings combined with the prestige of the victories he hoped to gain, to aid in detaching the allies from their fidelity and to isolate the Roman Republic proper in the midst of a surrounding hostile population. He saw that all depended on the initiative; and that if he could once gain a footing in Italy, as it were by surprise, he might afford to disregard any diversion his enemies might attempt to make by threatening Carthage.

2. It has been related that immediately before he crossed the Pyrenees Hannibal sent 11,000 of his Spanish soldiers back to their homes. This measure is an instance of that great knowledge of human nature which alone could have enabled him for so many years to rule an army composed of such discordant materials, so that "throughout the chequered series of his campaigns no mutiny, or even attempt at mutiny, was ever known in his camp." The explanation is as follows :—In the march to the Pyrenees about 3,000 Spaniards, frightened by the perils of the enterprise, deserted. Hannibal, sensible of the impolicy of attempting to prevent further desertion by severe measures which would indicate distrust, and feeling that unwilling troops weaken rather than strengthen an army,

gave out that he had himself sent the deserters to their homes as a reward for faithful service, and gave leave to 8,000 men on whom he could least depend to follow their comrades.

He thus took away the great inducement to depart; at the same time that he rid himself of doubtful followers whose bad spirit might have inoculated the remainder. This proceeding is one instance of the great value set upon moral agents in war, not only by Hannibal, but by every one who has the least pretension to be called a great general.

3. Scipio's apathy in remaining quietly at the mouth of the Rhone after he had ascertained that Hannibal had actually entered Gaul, is not to be excused. No pains should have been spared by him to discover the position of the enemy and the line of march by which he might be expected to approach the Rhone. He should have sent out his light cavalry to scour the country on the western bank of the Rhone, to bring him intelligence of the approach of Hannibal in sufficient time to enable him to co-operate with the friendly tribes of the eastern bank in defending the passage of the river. To facilitate this object it was necessary to occupy as central a position as possible. Probably one about midway between the sea and the Isara would have been best chosen.

When it is required to defend a long line—suppose the line of a river, and the point at which an enemy may approach it is uncertain—the general of the defensive force should not attempt to defend every practicable point of passage, for that would be impossible; and, even though it were possible, such a proceeding would too much disseminate his force, and would expose the separated fractions to be beaten in detail supposing the enemy to succeed, as it is most probable he would do, in effecting his passage somewhere. In such a case the general of the defensive force should keep his troops well in hand in some central position, lining the banks with his light troops to observe the approach and the intentions of the enemy. It should then be his aim to come down suddenly on the enemy while in the act of forming his bridge,—or, better still, after a part only of the hostile force should have crossed.

Failing in this, he should previously have named some convenient point of concentration in rear of his general line, commanding the

line by which the enemy must advance, where the defensive army in a strong position might successfully dispute the further advance of the enemy, and defeat him with the river in his rear.

Had Scipio occupied such a central position as has been supposed in the first instance, and, failing thereby to prevent the Carthaginian army from crossing the Rhone, had he concentrated his force in a strong position in the rear, Hannibal could not have reached the Alps without fighting a battle. It was the Roman game to oblige Hannibal to fight as often as possible at a distance from Italy, and thereby to cripple him before he could reach the theatre of his intended operations.

The passage of a great river in presence of an enemy is a great military operation. It may be effected either by main force, or by stratagem in deceiving the enemy as to the intended point of passage ; or, as Hannibal here exemplified, by a combination of both.

In general the passage of a great river which is defended by an enemy, is effected either by stratagem, or by force and stratagem combined.

In such a case, having divided the enemy's attention by demonstrations made by your light troops at various points along the river front, and having attracted his particular notice to some false point by manœuvres calculated to that end, you should then direct your columns as rapidly as possible on the real point previously selected, and throw your bridge across.

Alexander's passage of the Hydaspes is a striking illustration of these remarks, and there is a resemblance between that operation and Hannibal's passage of the Rhone, inasmuch as in both cases the first passage was won by troops detached to a distance from the main body, which afterwards moved down on the flank of the defensive force.

4. The resolution which Scipio took to send his army to Spain, its original destination, instead of carrying it back with him to Italy, shews that he was possessed of some of the qualities which go to make up a great general; particularly of that enlarged general view, without which a man may be an excellent tactician, but can never become a great commander. It is probably one of the rarest qualities of a general, the power of classifying in his own

mind the various events and circumstances which may influence the fate of a campaign, and giving to each no more than its due weight. It is to this faculty the great Napoleon alludes when he says: "The first quality of a general-in-chief is to have a cool head which receives only a just impression of objects; he should not allow himself to be dazzled either by good or bad news. The sensations which he receives successively or simultaneously in the course of a day should be classed in his memory so as only to occupy the just place due to each; for reason and judgment are the resultant of the correct comparison of many sensations. There are some men who, on account of their physical and moral constitution, make a single picture to themselves of every event; whatever knowledge, wit, courage, and other qualities they may possess, nature has not called them to the command of armies and the direction of great military operations."

Scipio foresaw that if the Carthaginians were unopposed in Italy, and had leisure to consolidate and to organise their conquests there, the safety of Rome would always be threatened, notwithstanding that Hannibal's army might be expelled from Italy, for the productive gold and silver mines of the Peninsula would constantly replenish the Carthaginian treasury; while the inhabitants—the best and bravest of barbarians, who were capable of becoming under the training of Hannibal and his brother equal to the best soldiers in the world—would afford a constant supply of recruits to the Carthaginian armies.

Arnold says: "Had Publius Scipio, at this critical juncture, not sent his army to Spain, instead of carrying it back with him to Italy, his son would in all probability never have won the battle of Zama." And indeed the progress of this narrative will demonstrate it to be more than probable, that if the Carthaginian forces, which were occupied in withstanding the Roman legions in Spain, had been at liberty to reinforce Hannibal in Italy, Rome could not have maintained the contest.

5. The position which Hannibal took up to the south-east of Placentia between the Roman army and Ariminum would have been in violation of the rules of war, if Hannibal had not been in a friendly country and therefore able to march and encamp in any

direction secure of obtaining supplies from the country-people. The violation of military rules would have consisted in this, that, although Hannibal had placed himself on the enemy's communications with Rome, the Roman army was based on Placentia, and it had moreover several magazines in the neighbourhood from which it could draw its subsistence, while its position intercepted Hannibal's communications with the country of the Insubrian Gauls, to which he must have looked as his base if the country south of the Po had not been also friendly.

But under the circumstances it was a masterly manœuvre, for Hannibal thereby placed himself between Scipio and the advancing army of Sempronius; and he doubtless did so with the intention of intercepting Sempronius, and of destroying him before he could unite with Scipio. Why he did not execute that intention it is impossible to explain. We learn that Sempronius marched from Ariminum and effected his junction with Scipio near Placentia. We know that Hannibal could not have been restrained by the weakness of his force, for he shortly after engaged the two consuls united; and he ought not to have failed from ignorance of the march of Sempronius for he had a numerous and excellent light cavalry in the Numidians who were the best scouts in the world. Whatever the explanation may be of his permitting Sempronius to pass him and to join Scipio, if it proceeded from any fault of his, which is very improbable, he speedily redeemed it.

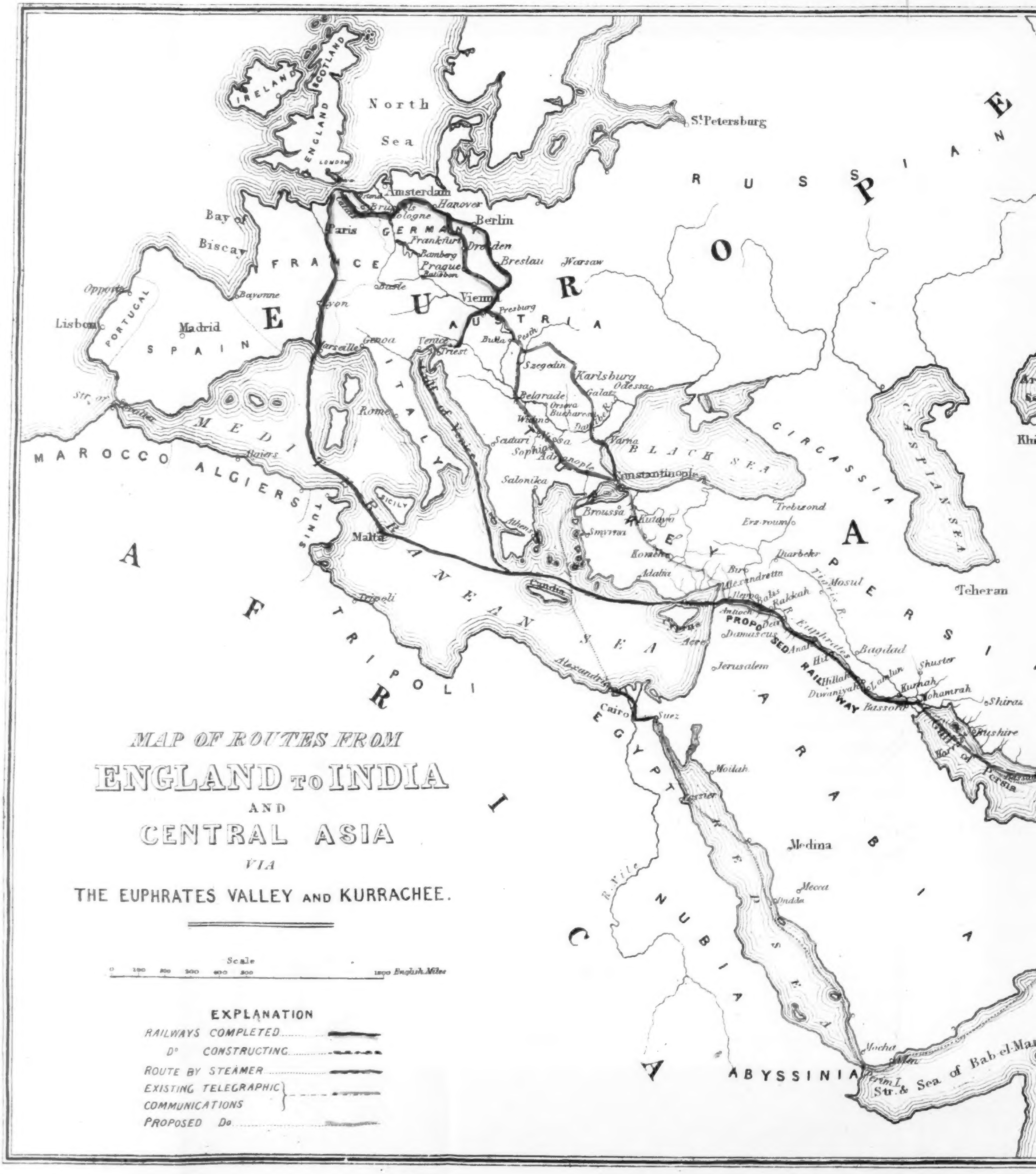
6. The conduct of Sempronius at the battle of the Trebbia is a remarkable instance of military incapacity. In war it is an axiom that every possible chance should be enlisted on your side. But the generalship of Sempronius arrayed every chance against him. Instead of leading into action men fresh and vigorous, his soldiers, fatigued with struggling through the deep cold water, fasting and nearly frozen, were launched against Hannibal's troops in the full vigour of their strength. This was "taking the bull by the horns" with a vengeance; and the river which the Romans crossed to engage the enemy added immensely to their losses when they recrossed it to escape from him. It is a maxim that you should never fight with a river or defile in your rear, because, although you may be victorious, in such a position defeat would be ruin;

and it is conceivable that even your chances of success would be diminished thereby, for men are not likely to fight so freely when they know their retreat is not secure.

7. The bravery and discipline of the Roman infantry which broke through the troops opposed to it and marched clear off the field to Placentia, were admirable. With Hannibal's numerous cavalry it is difficult to understand how he allowed this body to reach Placentia—it certainly seems that he should have prevented its doing so. A parallel to this march is to be found in the magnificent retreat of the three regiments of the Light Division under Crawford across the plain of Fuentes d'Onoro, in the face of an overwheming force of 5000 cavalry, 15 guns, and a large body of infantry in support.

8. The confidence Hannibal felt in the superiority of his own genius is manifested by his plan for fighting at the Trebbia.

In judging of ordinary men we should be inclined to censure the inactivity which permitted the Roman army to cross the river and to form leisurely on the bank, without taking advantage of the confusion necessarily occasioned by such an operation to attack and defeat it, when landing, before it could recover from that confusion. A general less self-confident than Hannibal, when about to engage his troops against an untried enemy, would have availed himself of the above most obvious and certain method of inflicting defeat. But Hannibal's policy was not only to defeat, but to destroy; and by the moral effect of the annihilation of his foe to intimidate the Romans, at the same time that he thereby confirmed his new-found allies in the belief that they would consult their best interests by remaining faithful to him. Had Hannibal attacked the Romans during their passage of the river their defeat would not have been less certain; but it would have been less decisive both in fact and in its moral effect. A much smaller number of Romans would have fallen; and both they and Hannibal's allies might have entertained, the one the boast, the other the reflection, that had the terrible Roman legions been arrayed against Hannibal on a fair field the result might have been very different.


MAP OF ROUTES FROM
ENGLAND TO INDIA
AND
CENTRAL ASIA
VIA
THE EUPHRATES VALLEY AND KURRACHEE.
Scale
English Miles
EXPLANATION
RAILWAYS COMPLETED
D° CONSTRUCTING
ROUTE BY STEAMER
EXISTING TELEGRAPHIC COMMUNICATIONS
PROPOSED Do.
PROPOSED RAILWAY
EUROPE
ASIA
AFRICA
IRELAND
SCOTLAND
ENGLAND
LONDON
North Sea
St. Petersburg
RUSSIA
Amsterdam
Hanover
Berlin
Bay of Biscay
Paris
GERMANY
Frankfurt
Dresden
Bamberg
Prague
Breslau
Warsaw
FRANCE
Basle
Lyon
Vienna
AUSTRIA
Presburg
Lisbon
PORTUGAL
Madrid
SPAIN
Genoa
Venice
Triest
Buda
Pesth
Marseilles
ITALY
Szegedin
Karlsburg
Odessa
Galatz
Belgrade
Orsova
Bucharest
Rome
Widino
Varna
Sophia
Adrianople
BLACK SEA
CIRCASSIA
Salonika
Constantinople
MAROCCO
ALGIERS
Algiers
TUNIS
SICILY
Malta
Athens
Broussa
Kutaya
Smyrna
Trebizond
Erzroum
Konieh
Adalia
Diarbekr
Mosul
Alexandretta
Aleppo
Antioch
Rakkah
Candia
Cyprus
Damascus
Acre
R. Euphrates
Tigris R.
Bagdad
Shuster
Jerusalem
Hillah
Kurnah
Mohamrah
Shiraz
Diwaniyah
Bussorah
Bushire
Gulf of Persia
Teheran
PERSIA
CASPIAN SEA
Tripoli
TRIPOLI
MEDITERRANEAN SEA
Alexandria
Cairo
Suez
EGYPT
Moilah
Medina
Mecca
Jidda
ARABIA
R. Nile
NUBIA
RED SEA
Mocha
Aden
ABYSSINIA
Perim I.
Str. & Sea of Bab el-Man

EMPIRE
CHINESE
EMPIRE
Aral Sea
Khiva
Bokhara
Caubul
Herat
Teheran
Peshawar
Attock
Lahore
Simla
Loodiana
Kurnaul
Delhi
Moultan
Agra
Benares
Ganges R.
Calcutta
Allahabad
Yezd
Shiraz
Bushire
Gomberoon
Bunpore
BELOCHISTAN
R. Indus
Hyderabad
Ajmeer
Ahmedabad
Nerbudda R.
Baroda
Surat
Bhopal
Jubbulpoor
Cuttack
Nagpoor
Oomrawatty
Aurungabad
Hydrabad
Bombay
DECCAN
Madras
Goa
Bangalore
Mangalore
C. Comorin
Colombo
Pt. de Galle
CEYLON
BAY OF BENGAL
Muscat
Massera I.
Bab-el-Mandeb
Socotra
ENGRAVED BY JAMES WYLD. CHARING CROSS EAST

Friday, July 31st, 1857.

COLONEL THE HONOURABLE JAMES LINDSAY in the Chair.

ON THE POLITICAL, MILITARY, AND COMMERCIAL IMPORTANCE OF THE EUPHRATES ROUTE TO INDIA.*

By MAJOR-GENERAL CHESNEY, R.A. D.C.L. and F.R.S.

LADIES AND GENTLEMEN,

I HOPE you will not be alarmed on looking at the formidable size of the sheet before you. An extensive line of country requires a good deal of paper, yet I fear that the fifteen feet by twelve Map before you will do but very imperfect justice to the illustration of the important, and, at this moment, the all-absorbing subject of our communication with India.

The Diagram before you, as you will at once perceive, extends from London to Delhi and Calcutta.

The blue line shows the existing railroad through Germany, and also that proposed to be laid down along the Euphrates, as well as some of the Indian lines.

The red lines are those of powerful steamers, to run at each end of the termini of the railways.

The small yellow lines are those of the electric telegraph, one going across Asia Minor to the Persian Gulf, and on to the Indus; a second from the Orontes also to the Indus; and a third passing down the Red Sea, and rounding Arabia to Kurrachee.

When all these shall be completed, passengers and mails—even with our present class of steamers—may be conveyed from London to Kurrachee in thirteen days and a half; and if by laying down electric wires we can, within the short space of eighteen or twenty hours, be assured of the welfare of some dear friend or relative who is in a distant part of India, two great objects will have been accomplished, which only a few years back, even the wonders of Aladdin's lamp, aided by the boldest and highest flights of fancy, could hardly have enabled us to imagine.

However, the fullest and most complete realization of these

* On account of the importance of this subject at the present time, the above lecture has been printed out of its order of date.

palpable advantages—which realization is probably close at hand—will be but a small part of the changes which must result therefrom. In fact, the construction of the intended railway is but *a part* of the question before us. It is far beyond any human power to foreshadow even faintly the changes which will follow the opening of a highway, and the annihilation of time and space, between the *East and the West.*

I cannot therefore expect or even hope to do anything like justice to the wide field which has fallen to my lot, of endeavouring to call your attention to the *political*, *military*, *commercial*, and, may I not add, the *social* importance of the Euphrates Valley route to India.

It is impossible to name this region of our globe without hosts of recollections of the past crowding upon our minds. To these, however, I shall but very briefly allude.

But we cannot name the Euphrates without remembering that we are there carried back to the earliest seat of mankind, to the *original spring* of *all* that has since flourished, and extended over our globe; in a word, *to Eden*, with its *rivers* which were "parted and became into four heads;" for the Hebrew equally bears the translation of a mass of waters. We see them now before us, and the very words of Moses describe them as truly now as they did when he wrote them.

The Halys, once the Pison, "compassing the whole land of Havilah, where there is gold, and bdellium (ascertained to be the pearl), and the onyx stone."

The Gihon, "that compasseth the whole land of Ethiopia," or Asiatic Cush, now the Arast, or Araxes, from Araxenes, son of Armenac.

The Hiddekel, or Tigris, so named from its well-known swiftness, and going as of old "towards the east of Assyria" and the Euphrates.

"And the fourth river is Euphrates," as if this name expressing everything, required no description from the inspired historian. Those who have seen it can well understand this; the great and noble river, destined to become the highway of nations, of commerce, and renewed civilization to the countries it traverses and fertilises.

To the Arab, the word *Frat* still *says* everything, and *is* everything.

The sources of these four rivers are not far distant from each other, nor from Mount Ararat. Two of them still bear their Mosaic

names; and the fourth river washes the remains of antediluvian Sippara as well as those of Babylon—the Babel of the Arabs.

Near its banks are also the remains of the other three primeval cities of Erech, Akkad, and Kalneh.

It may seem strange to speak of the remains of an antediluvian city. But we know that Berossus places Sippara in Babylonia; and Captain Lynch ascertained that the Arabs still preserve the name of this city in their Sifera, as they have also retained those of Babel, Akkad, and Kalneh. And these antediluvian remains will seem less strange if we recollect that the Deluge does not appear to have effected any great physical changes in the earth's surface. We know from Scripture that the olive-trees remained standing, and that the vine brought forth her fruit almost immediately after the subsidence of the waters.

In connection with the Euphrates and Babylonia we have the dispersion of mankind, and the peopling of Arabia and Assyria. We have the first empire of history—that of Nimrud the Assyrian. We have the earliest astronomical observations, so long preserved in Babylon—all this before coming to the departure of Abraham from Haran into Syria and Arabia, where he already found a numerous population—a proof, if any were wanting, of how rapidly population has spread and increased in a country so calculated by climate and natural advantages to foster its progress.

Later, we are reminded of the consolidation of Media, Assyria, Babylonia, Syria, and Phœnicia, under Cyrus the Great; and still later we find ourselves going over the conquests of Xerxes, following the younger Cyrus in his passage of the Euphrates at Thapsacus, and then retracing the battle of Cunaxa, and the retreat of the Ten Thousand.

With the reign of Alexander, however, we come to the first historical connection between Europe and India by this route.

He first *showed* us the feasibility of marching a large army by the line of the Euphrates to India.

From Egypt, Alexander advanced on the Euphrates, and crossed it at Thapsacus, where it is now proposed that one of the railway bridges should cross the river; marched and fought at Arbela; took Babylon, Susa, and Persepolis, and subjected the whole of Persia.

He saw and showed its importance in his great military operations. He overran Parthia, Media, Bactria, and advanced to the borders of the Caspian.

He crossed the Oxus and Jaxartes, and wintered in Bokhara. Thence he invaded India. What he did, others may now do also; unless indeed we fail to profit by the lesson to be learnt from the campaigns of this great warrior.

On the revolt of his troops he descended the Hydaspes and Indus, and commenced his homeward march.

We must not forget the voyage of Nearchus; we have had pilots by sea as well as our great pioneer by land in the proposed line. He marched on through Gedrosia to Susiana, where he was joined by Nearchus; and then his comprehensive mind saw the advantages of opening a trade with India, of planting colonies, and building cities in these fertile regions; and he did both. We must now follow him to the Lamlum marshes of the Euphrates, which remain unchanged to this day. The steamers of the expedition of 1835-36 navigated them with difficulty; and ague and fever, such as that which cost Alexander his life, still prevail in their neighbourhood. But a canal cut through these marshes would change this part of the country entirely; and I proposed to effect this by some such means.

While we in the present day march with such difficulty, and with such loss of men and horses, we are startled to find on a careful calculation that Alexander's army marched during these conquests 19,020 miles.

We must, however, bear in mind that Asiatics are capable of bearing much more fatigue in this way than ourselves, and I have myself had proof of this in the Persian army, which I have known to march 40 miles a-day for several consecutive days.

After the death of Alexander Seleucus became possessed of Western Asia, and we will pass over more than two centuries to come to the invasion of Arabia by Crassus—51 years before Christ. The Romans had discovered, as we have now done, that "Europe is no longer the world; and that the true key to the possession of the world is the Valley of the Euphrates and Tigris."

With a view to its conquest, Trajan proceeded to the East. He wintered in Antioch, took Nisibis, Edessa, and Ptesiphon, and,

descending the Euphrates, he cut a canal between the rivers, called the Nahr-Malcha and took his ships along it, and then down the Tigris to the Persian Gulf.

Next in review we see Zenobia pass before us, defeated in the plains of Antioch, her cavalry struggling among thistles, which rose above their heads, as they still would do.

Palmyra falls; and an interval of ten years brings us to the invasion of Julian the Apostate, and his descent of the Euphrates. According to Gibbon, he constructed a fleet on the Khabour, consisting of fifty large vessels of war, and 600 boats of wood, and 500 of osier, covered with leather.

These boats, described by Herodotus, are still in use on the Euphrates.

On the 7th of April, A.D. 363, Julian encountered a most terrific hurricane on the river, at a spot answering to the present El Kaim above Anah; and it is remarkable that it was apparently nearly at the same spot that the expedition which I had the honour of commanding was visited by a similar and equally fearful hurricane, in May, 1836.

After the siege of Perisabour, we must follow Julian's fleet through the Nahr-Malcha, which he had previously cleared out, down the Tigris to Seleucia. Here he burnt his fleet, and commenced his retreat. His death followed. Jovian succeeded to the command, and crossed the Euphrates with great difficulty at Dura or Tekrit.

From this period, A.D. 363, we have no record of any great military expedition in connection with Western Asia until Napoleon conceived the idea, in 1809, of transporting a force down the Euphrates, with a view to the invasion of India. All his calculations and arrangements were made for this end. His troops were to have been transported on rafts constructed of timber cut down in the vicinity of the sea coast, and on the banks of the river.

With a little of his daring we might do the same at this moment, and with much greater facility.

The garrisons in the Mediterranean might readily spare 7,400 men; of these 2,400 might go through Egypt, and 5,000 could be conveyed to the mouth of the Orontes in a few days. They

would then have before them a march of 110 miles, with ample means of transport to the river.* Pontoons, native rafts, and boats would carry the force down to the Persian Gulf in less than fifteen days. There, native vessels could be found to transport them to Kurrachee by a safe and rapid navigation at this season.

A few words will suffice to explain my first connection with the Euphrates.

In 1830 the late Consul-General Cartwright placed some queries in my hands respecting the relative advantages of the Red Sea and Euphrates lines of communication with India, and I set out as a volunteer, to obtain the desired information.

On my return from the Egyptian and Red Sea survey in 1830, I reported to Sir Robert Gordon on the practicability of a line from Bombay through Egypt, and on the last day of the year I commenced my descent of the Euphrates on a native raft constructed of timber and hurdles supported on inflated skins, only attended by an interpreter, an Arab guide, and two boatmen.

I was soon saluted by shots from the Arabs, who watched my progress from the banks, and I had to raise a parapet of sacks for shelter. The rest of my voyage was more quiet. I sketched the river by my eye, laying down its course, taking the bearings by the compass, and the soundings by means of a pole sunk through the raft to the depth of ten feet. As long as it passed clear, I knew we had that depth of water; and, whenever it met with any obstruction, I noted the depth on my chart. I was obliged to resort to this expedient to avoid awakening the suspicions of my crew.

At night the raft was secured to one of the numerous islands of the Euphrates, and, with the first dawn, we resumed our primitive voyage.

In this way we arrived at the singular fountains of bitumen at Hit. Here my raft was exchanged for one of those boats which make us practically acquainted with the construction of the ark, being "coated within and without with pitch."

The banks of the river presented a succession of water-wheels for

* Sir John Macneill met 1,453 camels, horses, and mules in one day between Suedia and Antioch, and was assured that on an average 1,200 camels and horses pass the toll-bar of Jesr-Hadid on the Orontes daily, or 10,000 in a week.

the purpose of irrigation, acqueducts, and remains of dams, which only require to be repaired to renew the unexampled fertility of this country. We know from Herodotus that ancient Assyria surpassed all other countries in productiveness, and that this was owing to the admirable and complete system of irrigation practised by the people.

A flat country, abounding in date-trees—the fruit of which is so fine on the Euphrates as to form a very large article of commerce—continues as far as Felujah Castle, opposite to Baghdad, and a bare country follows until you reach the neighbourhood of Babylon, where there are some very productive farms; but the ruins of the city itself are totally uninhabited, excepting by the lion and the bittern.

Here I exchanged my native boat for a more commodious one belonging to the residency, and continued my navigation through the Lamlum Marshes. I sailed among the singular inhabitants of this part of the river, who are, I believe, of Persian origin. They live in neat mat huts in the midst of rice-fields, and use extremely pretty and very swift canoes to go from spot to spot for labour or occupation. Some distance below Lamlum is the Arab capital, Sheikh-el-Shuyak; it is a considerable place, some of whose inhabitants live in mat and others in brick-built houses. A flat country, with date-trees and cultivation, continues from thence to Kurnah, the proposed terminus of the line of railway, for which it is admirably adapted on account of the deep water, which enables large and heavily-laden vessels to discharge their cargoes at once on the *natural quays* with which it is provided.

At the time of my voyage the dikes intended to keep this part of the river within bounds were in good repair, but lately they have been neglected, and the water has, consequently, been allowed to overflow its banks during the high season; a little labour, however, would restore these dilapidations, and lessen, if not prevent, inundations.

At Kurnah we entered the Shatt-el-Arab, a noble stream formed by the junction of the Tigris and Euphrates. Forty miles lower, Bussorah is seen on the right bank, and twenty-two miles lower down is Mohammerah, on the left bank.

There is an almost continuous belt of rich-bearing date-trees from Sheikh-el-Shuyak to the sea, a distance of 169 miles.

This ended my river navigation of 689 miles. I continued my voyage to Bushire; travelled through Persia to Trebizonde, thence through Asia Minor to Scanderoon and Aleppo; examined the Upper Euphrates, and returned through Asia Minor to Constantinople.

The river Euphrates offers such varieties of scenery that it is difficult to do more than give a brief and general description of its banks. Its two great branches, the Kara-Su, or black water, and the Murad-Su, or river of desire, rise near Ararat, and continue their course—the former for 450 miles, the latter for 586 miles—through a mountainous country until their junction. The banks are generally bold, high, and precipitous; the bed usually uneven and rocky.

The principal caravan passage is at Bir. The river is 140 miles from the Mediterranean, and is 628 feet above the level of that sea, and, as it rises 1,117 miles from the Persian Gulf, the fall scarcely exceeds six inches per mile.

As you proceed onward, its swelling hills resemble those which occasionally enclose the Rhine. Afterwards, for a time, it may be compared to the Lower Danube, and then again we are reminded of the Nile,—with its date-trees, and Arab tents. Occasionally it also presents the remains of stone walls, aqueducts, and water-wheels. The Euphrates, however, has features peculiarly its own, caused by a mixture of nomadic and settled inhabitants with their tents and houses, and by its numerous islands, some wooded, others having small towns built with or amidst ancient remains, some of which, in the time of Trajan, must have been important places; such as Deir, Ana Tilbus, Hadisa, El Oos, &c. The riverain population is still, however, considerable, and there is, consequently, a disposition as well as an opening for trade.

From the moment that I embarked on this noble river, my whole mind was filled with the contemplation of its immense capabilities. It seemed to me to be intended by Providence to carry Christianity and civilisation on its waters—to be once more, as of old, the fertiliser of the splendid country through which it flows—to be the restorer of that ancient commerce which once flowed so freely from the East to the West—and which the West might so easily, and with such

profit to herself, conduct back into its early channels. My chief fear was lest I should be forestalled in pointing out this line to India, and the capabilities of the Euphrates for steam navigation. I never shall forget my feelings on seeing, as I thought, one day *the smoke of a steamer* in the distance! It proved to be a flight of birds; but, until I had made this welcome discovery, I thought I had been forestalled; I little thought *then* that after *proving* the perfect navigability of the river by expeditions under myself and others, I should, after a lapse of more than twenty years, be still urging that this great undertaking should be carried out.

The result of my descent of the river was given in a report to Sir Robert Gordon and his successor Sir Stratford Canning. It was printed for private circulation in 1833, with a comparison of this and the Red Sea route.

His late Majesty William the Fourth at once commanded my attendance at St. James's, and after personally examining the maps, and perceiving that the Euphrates route had so little of open sea, he took up the question warmly, and continued to assist the cause most strenuously up to the time of his death.

The first great move was the appointment of a Committee of the House of Commons to examine the respective claims to support of the Red Sea and Euphrates questions; and, with reference to having a second route to India, £20,000 were voted by Parliament for an expedition to the latter river. This, as you all know, it was my lot to command. On landing in Syria we met with every possible opposition from Mehemet Ali, who refused us means of transport from the coast to the river, and threw every impediment in our way. We, however, succeeded in carrying a line of levels from the sea to the river, having reference to a canal or railway for this portion of the route, and succeeded, after ten months of exertion, in carrying our two iron steamers piecemeal across the country for 145 miles. We put them together at Port William, just below Bir, and accomplished the survey of the Mesopotamian rivers as had been intended.

When we had achieved about the half of the descent of the river, the terrific hurricane to which I have already alluded, carried the smaller steamer, the Tigris, to the bottom. But the river Euphrates

is not in any way more answerable for a calamity of this kind, than are our own shores to occasional disastrous storms. Ammianus Marcellinus is our authority for the partial destruction of Julian's fleet during the descent of the river 1,473 years ago; but neither history nor Arab tradition record any other instance of the sort. It is obvious, therefore, that we have little to fear, whether for navigation or for railway transit.

Soon after the return of the expedition three other river steamers were sent out, and the Euphrates was ascended, as far as Beles the port of Aleppo, by Captain Lynch and Commander Campbell of the Indian Navy, who afterwards descended the stream with the vessels. The pressure of the Afghan war caused their removal to the Indus, and as no steps have been since taken to replace them, either by Government or the East India Company, the navigation of the river has remained in abeyance.

There have been various proposals at different times for opening a communication with India by the Euphrates Valley. That which took the most practical shape was elaborated by Lieut. Campbell, then of the Royal Engineers, in 1843. His proposal and map were in all essential points identical with those more recently proposed by the great engineer Sir R. Macdonald Stephenson. These and many other subsequent proposals, both French and English, have all now become merged in the Company, of which Mr. Andrew is chairman, and Sir John McNeill the engineer in chief.

I was strongly pressed last year to join in the promotion of my favourite object of nearly a quarter of a century, and urged to proceed to Constantinople to obtain the necessary firman from the Sultan, and make all preliminary arrangements. Feeling that, with the prospect of a railway, a more careful examination of the country to be traversed was desirable, I was accompanied by Sir John McNeill, civil engineer, and two assistant engineers. We reached Constantinople by the route of the Danube, opened negociations, and made all preliminary arrangements with the Turkish government, and then proceeded to Syria, in H.M.S. Stromboli, which was placed at our disposition by Lord Lyons in the kindest manner possible. Nothing could have been more fortunate for us, since she was commanded by an officer, Commander Burgess, who proved himself to

be one of those men who *seek opportunities* of doing good service to their country; and most warmly was he seconded by Mr. Albert, the master, as well as the rest of his officers and men.

We examined carefully the coast of Asia Minor where the Taurus touches the sea, in the hope of finding a practicable valley for a future line through that country. The harbour of Alexandretta did not promise to answer, and the ancient harbour of Seleucia was also condemned as not having sufficient depth of water; but, on the southern side of the Bay of Antioch, a suitable spot was selected by Sir John McNeill, admirably adapted to form a safe and commodious harbour of refuge, which will be capable of receiving second-rate line of battle ships, and will be as good as, or superior to, the harbour of Kingstown. The Turkish Government is to bear the expense, and has engaged to construct this great work simultaneously with the railway.

The spot chosen is three miles south of the river Orontes. The harbour is proposed to be formed by running out a breakwater on the south side of a small natural harbour, at about three miles south of the estuary of the Orontes, and six miles south-east of the old port of Seleucia, which is now silted up by sand. A small outlay would render the site chosen for the new harbour a perfectly safe and secure landing-place for boats, so that vessels taking out materials for the construction of the railway could, in the summer months, anchor in safety off this landing-place, where there is good holding-ground; and here the various materials and plant that would be required to enable a contractor to commence work on the railway, could be landed without the risk and inconvenience of sending the boats over the bar at the mouth of the Orontes, which at times has only three and a half feet of water, and often a heavy surf, even with light winds from the west or south-west.

The breakwater or pier is proposed to be formed by the stone which abounds close to the point where the pier or breakwater will abut on the land. The stone is of the finest quality, and can be quarried to any extent at a very moderate cost, and run by trucks on a tramway into the proper position. It is proposed to construct about 1000 feet in length as speedily as possible in the first instance, which will give shelter to three or four vessels at a time to lie close along

shore at the proposed landing wharf on the north-east side of the harbour, which will save the expense and inconvenience of landing from boats; this proposed shelter can be afforded in eighteen months or two years, and will enable vessels drawing twenty feet water to lie in safety during the winter months, if required to do so. The pier or breakwater should be subsequently carried out much further, and have a cant of 1000 feet trending towards the north-east, so as shelter the whole harbour from the westerly and north-westerly gales—in any other point it will be sheltered by the land.

The expense of this harbour, estimated at about £350,000, will be borne by the Turkish Government: they expressed themselves as most anxious to commence this work, and to carry it out under the direction of Sir J. McNeill.

The harbour when completed will be capable of giving shelter to thirty or thirty-five large vessels—the average depth of water will be from twenty to forty feet.

In six months from the commencement of the work, a landing-place can be formed, and perfect shelter for the boats, at an outlay of £20,000.

Our survey of the country and the subsequent trial sections of the engineers extended from the coast to within sight of the Euphrates, taking in the towns of Antioch and Aleppo. Beyond the latter *all* engineering difficulties cease--the country presenting a hard dry level surface, called in Arabic Ká-jaledé, or *flat and hard,* most admirably adapted for a railway; and even between the Mediterranean and Aleppo the difficulties are such as would be considered *small* in this country. There will not be a single tunnel, and only two cuttings of any consequence: two chain bridges over the Orontes will be necessary ; but neither do these present any obstacles to engineering science of the present day. The average expense for the first part of this line, which will be the most expensive portion of the whole, is estimated at £13,484 per mile; and another portion, which also presents some difficulties, is £12,754 per mile; but as portions beyond Aleppo fall very considerably below this average, some of them being estimated at only £4,693 per mile, the average expense for the whole of this first section of the line from the

Harbour to the Euphrates has been calculated by Sir John McNeill at £8,858 per mile.

On my return to Constantinople the terms of the concessions were finally settled; but, owing to opposition from rival parties, they were less favourable than had been previously arranged. The Turkish Government gave a guarantee of 6 per cent. on the capital expended by the Company, requiring from them a deposit of £28,000 in exchange for the firman, with the condition that the works must be commenced within one year.

The expense of the whole line is estimated at £6,000,000; but assistance from our own Government is asked in some shape on the first section only, or on a sum of £1,400,000, since the railway, after reaching Aleppo, will require no assistance whatever.

I found the Porte thoroughly alive to the great advantages likely to result to Turkey from the establishment of this line. The consolidation of the Sultan's power in distant provinces of his empire, the great extension of commerce to be expected, the centralization of the system of Government—these and many other considerations were strongly felt by the Turks.

We found, indeed, the existing commercial returns in Syria most satisfactory. Without taking into account *any* increase, Aleppo alone and her commerce would suffice to support a railway thus far, and would yield a return of 8 per cent. to the shareholders. 1,800 shares were at once taken in Aleppo itself; and a petition was sent to the Sultan in favour of the railway. To the eastward of this city, however, a *large additional* trade may be expected; indeed, a very extensive trade *exists*, which would all flow into this railway. We shall have Syria and Mesopotamia on one line, India and Central Asia beyond, with Kurdistan and Persia on one side, and Arabia on the other. It is impossible to estimate the amount of traffic and commerce which will arise—it *must* be very large—it may be beyond what even England has ever seen or imagined, for there is no limit to the productive powers of these countries, provided capital and skill be employed to turn to account the vast provision for their fertilization contained in their noble rivers. The chief products at present are grain, which could be supplied to Europe to any extent. Cotton of a very superior quality—this

is already cultivated largely, but not yet well-cleaned, in the neighbourhood of Mossul, and would be grown much more extensively if any means of transport existed. My friend Mr. Rassam, Her Majesty's consul at Mossul, tells me that 100,000 camel-loads of cotton are now lying there for want of means of transport. Wool also, copper, sugar, indigo, saltpetre, dyes of various kinds, bitumen, and various other products, are the present ordinary exports of Mesopotamia.

Their demand for our goods would be proportionately large. At present the natives of Syria and Mesopotamia receive many of their supplies from Russia through Trebizonde; but their markets would be supplied by Manchester, Sheffield, Birmingham, &c., if the means of transport were but established.

It is, indeed, impossible to estimate the changes in European countries by throwing open to them these sources of commerce and openings for colonisation; and may we not humbly hope that it may be vouchsafed to us to carry back to our eastern brethren *those truths* and *that teaching* which came to us from thence, and to which we owe all the blessings and happiness which make England what she is?

This railroad, if carried out, will pass through a country hallowed by recollections too sacred to speak of here, but which every one present must *feel* and understand.

I have dwelt at some length on the commercial advantages to be expected from this line; although at this moment *even these* must yield in importance to the all-engrossing desire for more rapid communication with India. This, and telegraphic wires in operation, would be worth anything to England at this moment.

In speaking of the advantages of this line in its military, political, and commercial bearings, I would ask you to observe, that, with the same kind of vessels and equal means of speed in both cases, the entrance of the Persian Gulf will be reached in one or two days less time than the entrance of the Red Sea at Bab-el-Mandeb. But the difference of open sea *onward* is very great. From the Red Sea to Kurrachee we have 1,864 English miles—whilst we have only 718 from the head of the Persian Gulf to the same port, or less than one-half. In the one case we have the monsoon right ahead

towards Aden, in the other it is nearly abeam to Ormuz. I need scarcely add, a difficult and dangerous navigation in the one case, and a perfectly safe one in the other. It was this great difference in the open-sea distance of the two lines which made so great an impression on his late Majesty. When looking at the map, he at once said: "I am a sailor, and can appreciate this great advantage;" and up to his lamented death he warmly supported the Euphrates route.

The means of rapid and certain transmission of mails and passengers to India ought alone to decide the public and Government in favour of this line. For the transport of troops and stores it would be of inestimable importance.

Few political objects perhaps could be of more consequence to England than those which will be so thoroughly accomplished by this line; I allude chiefly to the consolidation and to the commercial and political resuscitation of Turkey. We have expended lavishly money and lives, ostensibly for this object, but without any benefit to ourselves, and without imparting any real *strength* to Turkey. By this line, however, we *secure* the defence of her frontier against Persia and Russia. You have already seen what a powerful influence has belonged at all times to the possession of the Valley of the Euphrates. A friend, who is intimately acquainted with the East, writes to me: "I was in those countries during the Russian war, and frequently thought how different the position of that power would then have been if their army had been moved in the direction of the Euphrates valley, instead of invading the Principalities and European Turkey. Europe would have remained in a state of apathy, and public opinion, *out of England at any rate*, would have been for them. Had they reached Mossul under these circumstances they would have been in a country whose resources surpass almost any other in the world."

This, or a very similar, plan was proposed to the Emperor Nicholas by one of his generals during the war of 1828-29. We may be thankful that it was not adopted.

Dr. Sprenger says: "If properly managed, the Valley of the Tigris would soon be sufficiently prosperous to form the basis of a campaign to the south-east, or the same route that was taken by the

Arabs when they conquered the Valley of the Indus in the seventh century of our era.

"The straits of Ormuz are so narrow that the Persian Gulf might at any time be converted into a lake belonging to the power which may be in possesion of Bussorah. *Europe is no longer the world; and the true key to the possession of the world is the Valley of the Tigris*, and not Constantinople, as it was believed in ancient times."

These are a few, and still but a few, of the great results likely to arise from the establishment of this line of communication. The subject is one of too great magnitude to be embraced in a lecture; but I trust I have said enough to give you an interest in its progress and success, and I will only add a few words on the subject of the *Arabs*, whose very name seems to inspire dread in many minds, and who are constantly represented as being hostile to the proposed railway.

The Arabs are a very singular, a very peculiar people. I have lived among them for many years—I have experienced their extremes of good and bad—the greatest fidelity to their engagements—the greatest truthfulness—the greatest hospitality and kindness from them in some instances, while in others I have been robbed by them. I have twice been led out to be shot by them—I was saved almost by a miracle, and yet these very Arabs lent me money when they released me, to pursue my journey, on the faith of my English word and name.

At one time during the Euphrates expedition, Mehemet Ali had set a price on my head—still not an Arab took measures to secure this reward, although "Chesney Beg," as they called me, was more than once in their power.

Our chief difficulties with the Arabs would arise from their ignorance, the divided and sometimes hostile state of the tribes, their blood feuds, and their occasional breach of faith. Of this I myself experienced an instance, for, instead of performing their promise of taking me round the Dead Sea, they carried me and my party off into the Desert, robbed us, and kept us some time for a ransom. Notwithstanding this, the journey was in many respects a very interesting one, and we escaped at last by disarming one of them, when they were in reduced numbers, and recovered our money.

The story is too long to tell, but it was stated at Damascus that this *mistake* arose from there being no one at that time to keep the Beni Sakka tribe in order.

On the other hand, I must observe that such a breach of faith is the exception to what I have usually met with from this people. During the Euphrates expedition their caravans carried for us large stores of muskets, powder, and ammunition, as well as considerable sums of money, to the amount of £6,000 or £7,000, attended only by one individual of our party, and in no one instance was there *any* loss to us. These undertakings were usually paid in advance; and, when the Arabs were prevented from fulfilling their engagements, the money paid was scrupulously returned to us. It is a startling fact, that neither during the expedition I commanded, nor those which followed, which occupied several years, did we lose a single man by the Arabs.

They are, indeed, as much alive to their own interests as other nations, and will soon appreciate the advantages which they will derive from the railroad by regular employment of themselves and their camels, and increased trade. If, however, they should show hostility contrary to all expectation, such arrangements have been made with the Sultan's Government as will meet even this difficulty. It must be remembered also that a body of workmen such as we must employ, amounting to 10,000 or 12,000, are already a considerable defensive element; and we should also recollect that Ibrahim Pasha kept the Arabs under perfect control.

In addition, however, to my own opinion, I will read to you that of a friend, Dr. Aloys Sprenger, the first orientalist of the day, and who has resided for *many* years among them. His description of the Arabs is too good to be omitted.

"Some time back I received a letter from Mr. Porter, at Damascus, expressing great uneasiness on account of the Bedouin, but nothing can be more unfounded than this cause of alarm, for the Bedouin are the most manageable people in the world if judiciously treated. But, even if matters were to be mismanaged as they have been at Aden, and the Bedouin should offer every opposition in their power, it would be of little avail. It would soon be found that, notwithstanding their personal bravery and cunning, they are

very much like wild beasts; no one has ever heard of an army of tigers, and so it would be with the Bedouin, who have never been united. Like wild beasts they would show desperate courage when irritated; but such ferocity can do nothing against discipline and calm resistance. As a proof of this, I may mention that there are some Kurdish villages below Mardin, in the midst of the desert which, small as they are, defy all the power of the Shammar tribe, and successfully refuse to be taxed. Whoever posseses the Euphrates has the Bedouin in his pocket, for this cuts them off, and they cannot do without its water, and other resources. Those who really entertain fears of the Arabs forget that a railway running through a fertile country is a vein of life. In less than ten years we shall see towns and villages springing up on both sides of the line, and thousands of these nomades settled in them.

"N.B.—It has been arranged that the Sultan is to give the necessary protection if the Arabs do not further the railway of themselves."

In confirmation of the opinion here given of the manageableness of the Arabs, I may mention that by means of a marriage, and by giving, myself, a small portion to the bride, at the same time reminding them that the Koran inculcated peace, I settled a blood feud of long standing between two hostile tribes.

It is, however, on a gradual operation that I build for bringing all things right, and for this reason I took no part in the proposal for laying down the electric wires through Arabia at present. From the difficulties to which I have alluded in dealing with the Arabs, you will easily understand that I considered isolated wires passing through their country as very insecure. I however thought it right to open negotiations at Constantinople on this subject, and I also arranged with Mr. Barker, Her Majesty's Vice-Consul at Aleppo, who has passed his life in that country, that he should, if required, go among the Arabs to make preliminary arrangements for the establishment of the telegraph, by opening, in the first instance, the line of Tartar posts which were in use in Lord Wellesley's time.

The principal points of this question are now before you. Each individual will form his own opinion as to the desirability and practicability of carrying a railway and electric wires through

Arabia. I assume the affirmative in both cases, and if I were twenty, or even ten, years younger, I should be very happy to prove on the spot that I am right. But I feel that at my time of life I should be doing mischief to a great cause; and surely this ought not to be the case when my place can be supplied by an officer of great perseverance and singular uprightness (provided he would undertake the charge). I allude to Capt. Charlewood, R.N. This officer is in the prime of life, understands the management of railways, and not only has had great experience of the Arabs, but he knows the country, and also practically what is necessary to carry out the navigation of the river Euphrates.

I have now only to add that I hope I have not trespassed at too great length on your time, and that you will henceforth feel some little interest in the progress and success of the Euphrates Valley Communication with India.

Evening Meeting.

Monday, June 15th, 1857.

Colonel the Hon. JAMES LINDSAY in the Chair.

NEW MEMBERS.

The Chairman announced that 18 new Members had joined the Institution since the last Meeting, viz.:—

LIFE MEMBERS.

Earle, William, Capt. Gren. Gds.

Foster, T., Col. Royal Engineers.

ANNUAL SUBSCRIBERS.

Earlsfort, Lord, Lieut. 1st Life Guards
Hayter, Arthur D., Lieut. Gren. Gds.
Foster, B. L., Lieut. Royal Artillery.
Brown, H. Newton, Capt. 2nd West York Light Infantry Militia.
Aldred, John Wm., Lieut.-Gen.
Griffin, J. H., Col. Royal Artillery
Moore, Jno. Croft, Lieut. Rifle Brigade
Dowdeswell, W. F. Lieut. 7th Dragoon Guards.
Nicholl, Hume, Lieut. 7th Drg. Gds.
Echalaz, R. C., Cornet 7th Drg. Gds.
Ferguson, G. A., Capt. Gren. Gds.
Douglas, John, C.B., Lieut.-Col. 79th Highlanders.
Clerk, A., Capt. Royal Artillery.
Dacres, Sir R. J., K.C.B., Maj.-Gen. Royal Artillery.
Ellis, W. B. E., Lieut. Royal Artillery
Cameron, John, Capt. Royal Engineers.

INCREASED SUBSCRIPTION.

The under-mentioned Officer had raised his Subscription from Ten Shillings to One Sovereign since the last Meeting:—

Dacres, Sir R. J., K.C.B., Major-Gen. Royal Artillery.

DONATIONS.

List of Donations from 1st to 15th June.

To the Library.

Papers on Subjects connected with the Duties of the Corps of Royal Engineers. New Series, Vol. VI. Presented by the Editors.

ON THE MOLECULAR CONSTITUTION OF THE METALS OF ORDNANCE, AS AFFECTING ITS CONSTRUCTION AND ITS WEAR IN SERVICE.

By Robert Mallet, Esq., C.E., F.R.S., &c.

Within the limits of a single Lecture it will not be possible to do more than glance at some leading characteristics of a large and important subject, the complete treatment of which requires more than one volume, and which, old as is the art of gun-founding, remains yet in great part to be written. I shall confine myself at present, amongst the metals which may be viewed as peculiarly those formative of artillery, namely, cast iron, wrought iron, steel, and bronze, to the three first, reserving for perhaps some future occasion any remarks upon the last, the most compound and complex, and, though the oldest used, perhaps still the least understood material of ordnance. And again, in the remarks I purpose making upon iron in its three remarkable states—cast, wrought, and steel—as materials for ordnance, I propose restricting myself to some views as to the molecular constitution of these metals :—

1st. As influencing the proper form of cast-iron guns ;

2nd. As determining the proper construction of guns of wrought-iron ;

3rd. As affecting the wear and tear of guns in service—in explanation of the hitherto misunderstood phenomena called "drooping at the muzzle."

Incidentally, a few remarks may occur with reference to steel and bronze.

I speak in presence of many who upon the well-fought field, or before the shattered tower, must have had frequent opportunities of observing guns burst in service, and who will have probably remarked a certain general uniformity of direction in the fractures—a common method, as it were, according to which a gun (if sound) always bursts—but probably also without having attempted either to analyse the conditions upon which uniformity under such apparently accidental and capricious circumstances rests, or to follow out to their consequences, as regards the gun itself, the law of such conditions

when ascertained. I propose, in the first place, briefly to trace both of these.

The Plate No. 1 shews by the heavy dotted lines the almost invariable directions in which fracture takes place when cast-iron guns burst in proof or in service. Assuming no serious flaw or other defect to exist anywhere, the gun splits up nearly into equal halves, usually by a vertical or nearly vertical plane, passing through the axis of the piece, and extending from the breech-ring, which it often also divides, longitudinally to a point a little in advance of the trunnions, where it turns out to one side and to the other, leaving the muzzle portion of the gun for a length of between two-fifths and one-third its whole length unbroken. This portion of the gun at the moment of fracture is thrown forwards, partly by the direct action of the powder-blast escaping, partly through the unbalanced action of the elastic forces within the strained metal suddenly released, and partly by the friction of the passing-through shot. It usually falls to the ground with the muzzle end foremost, and as this strikes the ground the mass throws a somersault, and is found lying along in the line in which the gun had been trained, but with the direction of the muzzle reversed, or pointing backwards, a circumstance often remarked upon with surprise by artillery officers, but which is thus easily accounted for.

Sometimes the portions of the gun at and in rear of the trunnions are divided by other fractures in planes more or less completely at right angles to the preceding one, and by several "turn out" or transverse fractures. These latter occur and are more numerous in proportion as the metal of the gun is harder, more highly elastic, and more rigid, and as the bursting charge is more powerful—in a word, the fragments are smaller and more numerous, and more irregular, when the rending forces are greatly in excess of the resisting powers of the metal.

The fractures of bronze guns are of a somewhat different character, and the fragments are bent and distorted, both owing to the greater toughness and ductility of the material.

Three circumstances are specially worthy of attention as indicated by the lines of fracture thus generally described :

1st. The dividing longitudinal plane, whether vertical or hori-

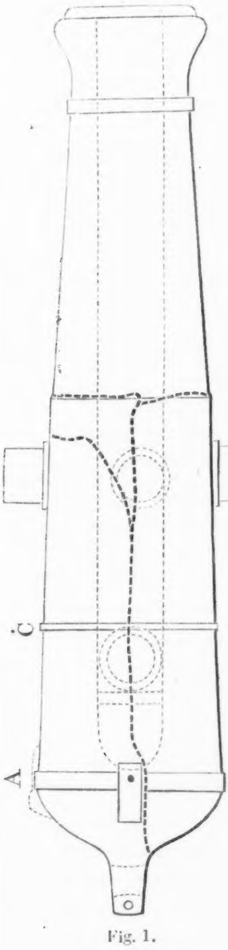
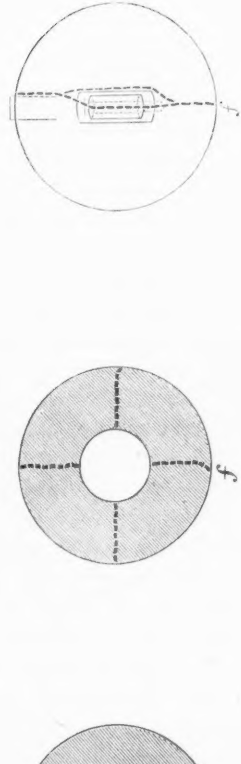


Fig. 1.



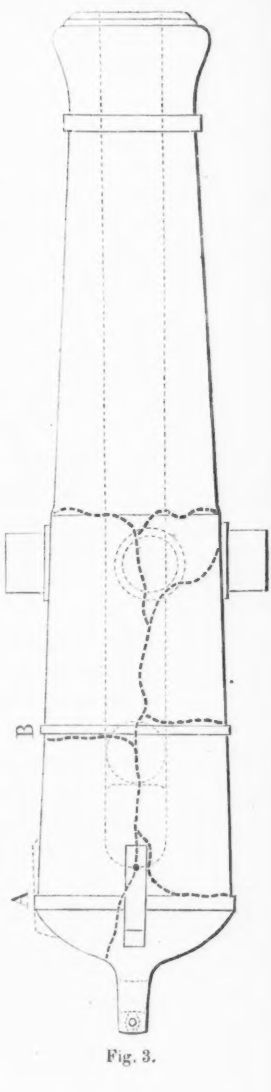


Fig. 3.

zontal, is always found to assume a sudden curved form, as in diagram, at one or other side of the exterior of the gun; indicating that the fracture begins at one side *s*, that opposite to the inflected fracture, and that fracture has spread from that side, the gun opening out and the divided surfaces turning from each other upon the point of inflection at *e* as the hinge.

2nd. Fracture therefore appears in all cases to commence at the interior of the chase, and to propagate itself outwards, thus rending the metal from within to without; a result which, though difficult at first to reconcile to the imagination, is pointed to by every mathematical investigation of the resistance of cylinders to internal fluid or elastic pressure—leading to whatever formula—since *the metal must yield first when the pressure per square inch is greatest upon its resisting unit of section, and this is in the interior of the thickness.*

3rd. The planes of fracture follow the track, with almost unerring precision, of all re-entering angles, and of all sudden changes of scantling or dimension, however trifling, in the external contour of the gun. Thus a vertical longitudinal fracture often passes through the vent (as being the weakest part in section), but much more frequently follows along the re-entering angle made along the exterior of the gun at its meeting with one or other side of the vent field, as in fig. 1 and fig. 3. The transverse fractures, though often more or less diagonal to the axis of the gun, also mainly follow round, with remarkable regularity, the small re-entering angles made by the several breach or reinforce mouldings on the exterior of the gun, while those which approach the trunnions usually fall into the re-entering angles made by these with the body of the piece.

No doubt these facts are familiar to every one who hears me, but I am not aware that the value of their correct observation has hitherto been recognised, or that any attempt has been made to assign a cause for them, or, in fact, to attribute the directions into which a burst gun breaks to anything more than "accident."

I proceed to explain the cause. It is a law (though not noticed,

so far as I know, by writers on physics,) of the molecular aggregation of crystalline solids, that when their crystals arrange themselves under the influence of heat in motion, these arrange and group themselves with their principal or long axes in lines perpendicular to the cooling or heating surfaces of the solid, that is, in the lines of direction of the motion of the heat, and this is true whether in the case of heat *passing from* a previously fused solid in the act of cooling and crystallizing on consolidation, or of a solid not having a crystalline structure, but capable of assuming one upon its temperature being sufficiently raised by heat applied to its external surfaces, and so *passing into* it.

For example, if an ingot of sulphur, antimony, bismuth, zinc, hard white cast iron, or other crystallizable metal or atomic alloy, or even any binary or other compound salt, or haloid body, as sulphuret of antimony, calomel, sal ammoniac, various salts of barytes, and lime, chloride of silver or of lead, chromate of lead, or even organic bodies, such as camphor and spermaceti, provided only they be capable of aggregating in a crystalline form under the influence of change of temperature, as from fusion or sublimation—if an ingot or mass of any such body be broken, the principal axes of the crystals will always be found arranged in lines perpendicular to the bounding planes of the mass, that is to say, in the lines of direction in which the wave of heat has passed outwards from the mass in the act of consolidation.

But, conversely, the same effect is found to be produced by the application of heat (far below that of fusion) to the surfaces of solids, which are capable of solidification in either of the two states, homogeneous (amorphous) or crystalline. Of such bodies many are known. For example—many of the metals, glass, carbon in certain states, ice, chalk, when crystallizing into marble under pressure and ignition, oxide (litharge), and iodide of lead; and amongst even organic bodies—sugar, paraffino, spermaceti, &c.

If a cylinder of lead of some four or five inches long, and about the same in diameter, be cast around a round bar of iron of about $1\frac{1}{2}$ inches diameter, and some two or three feet long, the lead on becoming cold, and rapidly consolidated by the contact of the cold iron bar interiorly, will have a perfectly homogeneous structure; it may be cut into, beaten out, &c., but presents no trace of crystallization.

If, however, one of the projecting extremities of the iron central bar be now placed in a furnace and heated red-hot, and time be given until the heat conducted along the bar, and from it passed into the interior parts of the lead cylinder, and thence transmitted outward radially through the latter in all directions, shall have raised the temperature of the lead itself to within a few degrees of its melting point, say to about 550° Fah., and the lead be now struck sharply with a hammer, the whole mass will be found to have assumed internally a crystalline structure; all the principal axes of the long thin crystals radiating regularly outwards from the axis of the cylinder to its surface, and by a few blows of the hammer the whole mass will separate and fall to pieces as a metallic dust; so complete are the planes of separation of the crystals. (See Plate II. fig. A.)

A piece of cylindrical brass wire, tough, fibrous, and presenting no traces of crystallization, may in the same way be caused to become almost instantly brittle and crystalline, if passed endways into the centre of a red-hot iron tube of small diameter (such as a gun barrel), held vertically.

A flat plate of thick rolled or malleable zinc, which is nearly homogeneous in structure, or, if not so, presents fibres and lamina in the plane of the plate, if laid down flat upon a cast-iron plate, and heated to within a few degrees of its melting point, assumes very soon a crystalline structure, the crystals having their principal axes now all cutting perpendicularly through the plate from side to side; in other words, the internal structure being in this and the former case absolutely turned round 90° of angular direction.

The same change of structure takes place more slowly in glass: when exposed for a considerable time to a heat short of fusion, or even complete softening, it is converted into the opaque substance known as Reaumur's porcelain, in which a crystalline structure is developed, and the principal axes are arranged perpendicular to the surfaces recipient of the heat.

Many other instances might be adduced, were this the place to pursue so tempting a subject; but enough has been given to indicate the generality of the law.

Now cast iron is one of those crystallizing bodies which, in con-

solidating, obeys, more or less perfectly, according to the conditions, this law also; so that generally it may be enunciated as a fact, that *in castings of iron the planes of crystallization group themselves perpendicularly to the surfaces of external contour; that is to say, in the directions in which the heat of the fluid cast iron has passed outwards from the body in cooling and solidifying.*

Because the crystals of cast iron are usually small, and are never very well pronounced, these directions are seldom very apparent to the eye, but they are not the less real.

Their developement depends—

1°. Upon the character of the cast iron itself; whether it contain a large quantity of chemically uncombined or suspended graphite or not, which Karsten has shown to be the case with all cast irons that present a coarse, large-grained, subcrystalline, dark graphitic or shining spangled fracture;—such irons form, in castings of given size, the largest crystals.

2°. Upon the size or mass of the casting, the largest castings presenting, for any given variety of cast iron, the largest and coarsest aggregation of crystals, but by no means the most regular arrangement of them, which depends chiefly upon—

3°. The rate at which the mass of the casting has cooled, and the regularity with which heat has been carried off, by conduction from its surfaces to those of the mould adjacent to them; and hence it is, that of all castings in iron those called "chilled," that is to say, those in which the fluid iron is cast into a nearly cold and very thick mould of cast iron, whose high conducting power rapidly carries off the heat, present the most complete and perfect development of the crystalline structure, perpendicular to the chilled surface of the casting. In such the crystals are often found penetrating 1½ inch or more into the substance of the metal, clear and well defined.

These prevailing directions of crystalline arrangement may be made more clear to the eye by the Plate II. No. 2.

Figs. 1 and 2 are sections of a round and a square bar of any of the crystalline solids we have spoken of, or of cast iron when

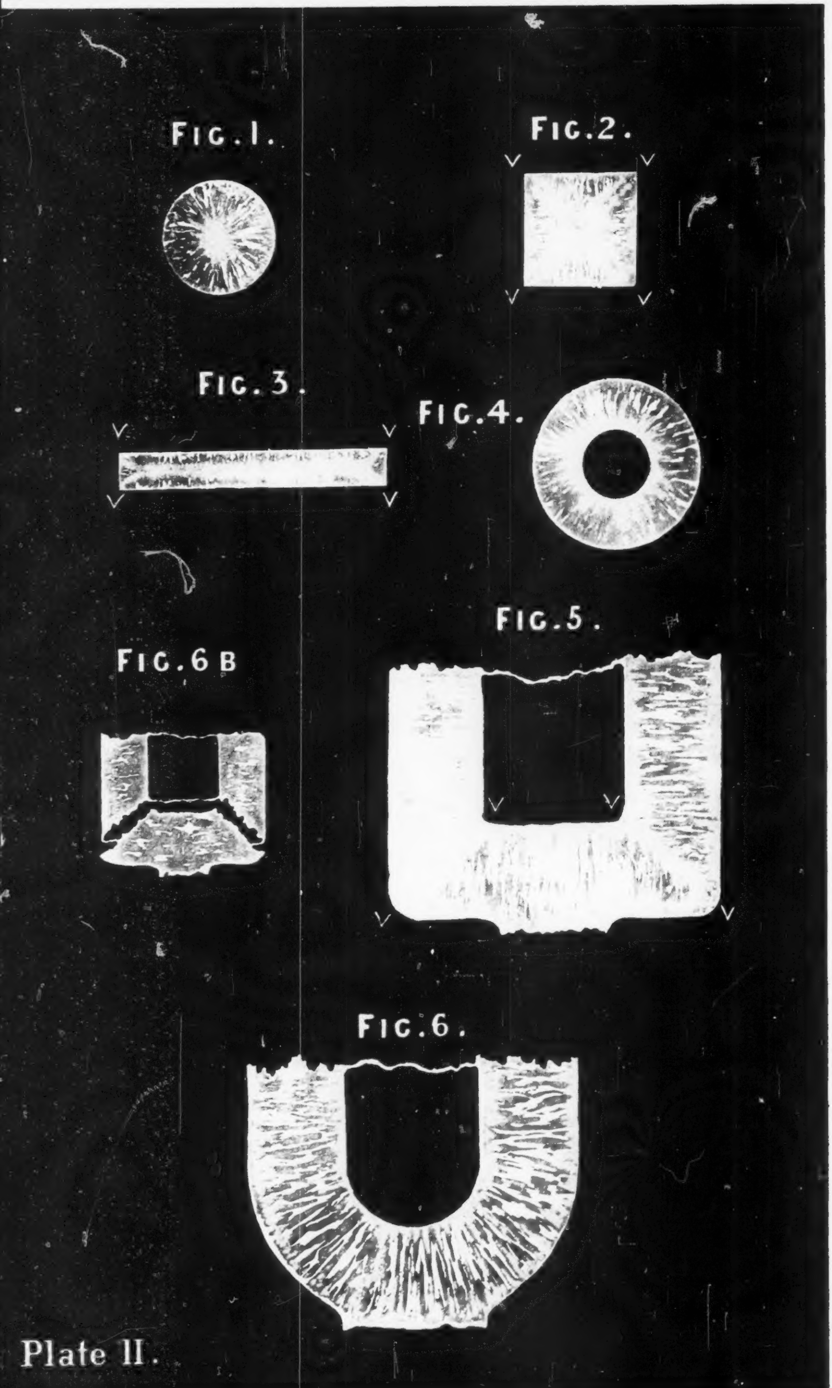


Plate II.

FIG. 9.

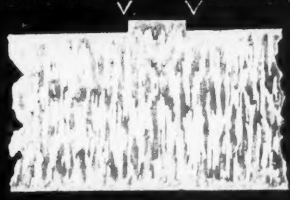


FIG. 7.

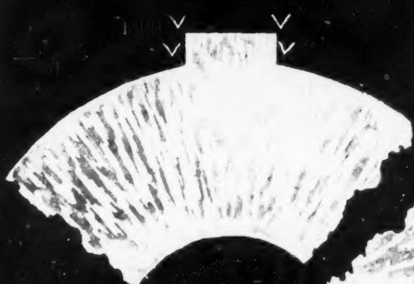


FIG. 8.

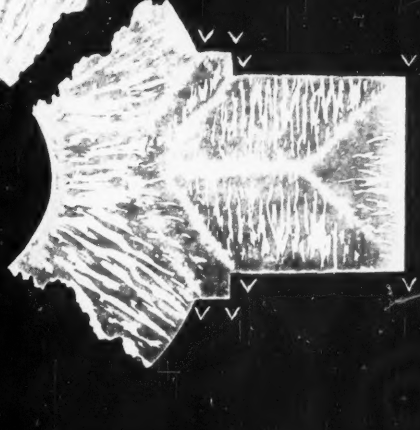


Plate II A.

the crystallization is well developed (the circumstances affecting which we shall consider further on). In the round bar the crystals all radiate from the centre; in the square bar they are arranged perpendicularly to the four sides, and hence have four lines (in the diagonals of the square), in which the terminal planes of the crystals abut or interlock, and about which the crystallization is always confused and irregular.

In fig. 3 a flat plate is shown in section. The directions of the crystalline axes follow the law of No. 2, with an expansion in one direction.

In fig. 4 a section is shown of the hollow cylinder of lead alluded to (ante, page 170), in which, as in the case of fig. 1, the arrangement of the crystals is always towards the centre or axis of the cylinder. This figure also applies to every cast iron hollow cylinder, whether water-pipe, gun, mortar, &c.

Fig. 5 represents a portion of the lower or closed end of the cylinder of the hydraulic press as first made for the purpose of raising the tubes of the Britannia Bridge, and which broke in the attempt; the end of the cylinder having broken out from the sides, in the form of a fracture of a cone, as in fig. 5 B, under the severe water pressure to which it was exposed; that is to say, the fracture took place all round, along the plane of junction of the conterminous crystals, formed perpendicular to the external and internal surfaces of the bottom and of the sides of the cylinder, proving that such planes of junction existed as in figs. 2 and 3. The crystals here join and interlace confusedly; these are *planes of weakness*—planes in which the cohesion of the metal is less, and for this reason, than in any other parts of the mass. These *lines of weakness* extend from V to V throughout all the figures. The form of the bottom of this cylinder was changed by Mr. Stephenson, from a distinct appreciation of the fact, that the fracture of the first was in some way connected with the sharp and sudden termination square to the axis of the cylinder, though without apparently any clear conception of the crystalline laws upon which the fact depended, and a new cylinder, with a sort of hemispherical end, was made, a section of a portion of which is represented in fig. 6. This stood the strain uninjured. Here the principal axes of the crystals all are directed, as in figs. 1 and 4, to

the centre. They therefore *gradually* change their direction, and no planes of weakness are produced.

It is to be hoped that these illustrations have served to make clear the general law as applied to cast iron artillery, that *every abrupt change in the form of the exterior, every salient, and every re-entering angle, no matter how small, upon the exterior of the gun or mortar, is attended with an equally sudden change in the arrangement of the crystals of the metal, and that every such change is accompanied with one or more planes of weakness in the mass.*

Figs. 7 and 8 are sections of portions of a large cast iron gun. The former one of part of the breech through the "vent field" square to the axis of the bore. The latter, a section near a trunnion, also square to the axis. Fig. 9, a section of a reinforce ring in the plane of the axis. In all of these are shown, in an exaggerated form, the directions of crystalline aggregation, and the planes of weakness resulting from it.

It will be remarked that the square projection of the "vent field" produces at each salient and re-entering angle planes of weakness, which in the case of the latter angles penetrate deep into the thickness of the gun: and that these planes really do exist, is evidenced by referring back to Plate No. I. in which it will be seen that the lines of fracture in burst guns almost always follow along the angle at the sides of the "vent field."

So also in the case of the trunnions (fig. 8). On referring back to the same diagram, it will be seen that the great planes of cross fracture usually turn out and meet the exterior of the gun just at the re-entering angle of the trunnion with the body of the gun. A gun, like every other body that fails under strain, must fail in the weakest place. We have shown in what places they do fail, and we have shown, *à priori*, what must be the weakest planes (for a given material and mass), and we have found that the places of fracture and positions of these "planes of weakness" most remarkably coincide. The conclusion therefore seems inevitable, that, however incapable the unaided eye may be to discern any difference in the crystalline arrangement of one part of the gun more than of another, such planes of weakness do exist, in the positions and from the causes here pointed out.

The external forms of cannon have been greatly modified and simplified of late years from the complex and highly ornamented (?) forms of former periods; but even still, in the plainest forms of guns, such as Sir William Congreve's patterns, Monk's, &c. mouldings, astragals, reinforces, &c. are still adhered to, and, from unwillingness to give up altogether, antiquated forms, adopted and continued in ignorance, we have the folly still to cling to making numerous sharp angles and corners, and sudden changes of form and of dimensions, on the exterior of all our ordnance, and so prolong, in the most needless way, one cause of their weakness. That gun, however plain externally, will look best to the really educated eye that most fully conforms to the laws upon which its perfection as an instrument depends.

Some remarks should now be added as to the effects upon the strength of guns which circumstances, brought into play in the processes of moulding and casting them, exercise, extraneous to those which we have already treated of as respects the directions of aggregation of the crystals of the metal.

Although not my intention to go at all into questions referring properly to the iron-founder's art, to practical methods, better or worse, or to the details upon which sound or defective castings depend, as these, though most important, do not find a fitting place here, it would yet be desirable to consider,—

1. Upon what circumstances the more or less complete homogeneity of the crystalline alloy we call cast iron depends when cast into guns, and therefore how, with the best or with any external form, we may most avoid the formation of "planes of weakness," so far as the moulding and casting are concerned;
2. The effects due to the contraction of the metal in process of cooling, and of sudden changes of mass or of dimension upon this;
3. The effects of rapid and of slow cooling, and of unequal cooling;
4. The effects of casting under the fluid pressure due to increased "head" of molten metal;

and to add a few remarks upon the presumed relative advantages so

much and so loosely talked of latterly, of cold-blast and hot-blast iron, and of foreign and British iron, as materials for ordnance; these, however, I must pass in a very cursory manner. It is known to every practical iron-founder upon a large scale that generally the larger the mass of the casting he makes with any given quality of cast iron the "*coarser is the grain*," that is, the larger are the crystals that develope themselves in the mass. The same metal that shall produce a fracture bright gray, matted, and without a crystal visible even to a single lens, when cast into a bar say two inches diameter, shall, if cast into a cylinder of two feet in diameter, produce a dark confusedly crystalline surface of fracture as coarse as granite rock.

To meet this, the practice is to prescribe for material for large castings a certain large proportion or mixture of "small close-grained scrap metal" with the pig iron, of whatever quality may be directed. The remedy fails, as fail that always must which is founded upon a misconception of the laws of the phenomena. As well might small seeds be sown to produce small trees. The small scrap is no sooner cast into the large mass than it assumes the large crystalline grain. Again, by some iron-founders one "make" or sort of pig-iron is presumed to give a closer grain than another, and he prefers it; and although this is to a certain extent true, *i. e.* that some cast irons—that is, some of the innumerable alloys that go under that name—do, under equal conditions, produce rather smaller crystals than others, still this view equally fails to attain the object of *close-grained heavy* castings. But, furthermore, it is a fact familiar to iron founders, that of several castings of the same form and mass, made at nearly the same time from the same mixture of metal, and melted in the same furnace, some will when cold have a much more coarsely crystalline grain developed in them than others. The fact is familiar, but I am not aware that any attempt has been made on principle to explain it, and hence no means taken to prevent its occurrence.

Now while the *regularity of developement* of the crystals in cast iron depends as we have already seen upon the regularity with which the melted mass cools, and the wave of heat is transmitted from its interior to its surfaces, arranging the crystals in the *lines of least pressure* in its transit, the *extent of developement*, or, what is the same

thing, the size of each individual crystal, depends upon the length of time during which the process of crystalline arrangement is going on, that is to say, upon the length of time that the casting takes to cool. Hence then it may be announced as a law, that

The size of crystals, or coarseness of grain, in castings of iron, depends, for any given make of iron and given mass of casting, upon—

> 1st. The high temperature of the fluid iron above that just necessary to its fusion;
>
> 2nd. Upon the time that the molten mass takes to cool down and assume again the solid state.

The conclusion and rule that I deduce from a wide and careful consideration of all the conditions affecting the formation by casting of cast-iron guns is, that

greatest contraction for small casts + least for large cast of same iron

> The lower the temperature at which the fluid cast iron is poured into the mould, and the more rapidly the mass can be cooled down to solidification, the closer will be the grain of the metal, the smaller its crystals, the fewer and less injurious the "planes of weakness," and, cæteris paribus, the greater the specific gravity of the casting;

in fact, the better the gun, from whatever sort of cast iron it may have been formed.

I have shewn, too, by experiments made upon a very large scale, the results of which may be found in the Transactions of the British Association for 1840, and also in my work on the Construction of Artillery (1856), the important effects producible by casting under a great head of liquid metal, an increase of density of metal under a head of 14 feet = about 44·8lbs. pressure per square inch being obtained (with some makes of iron) in the ratio of 7·1035 : 6·9551.

Some experiments made in the United States upon this point have led to indecisive results, but only because the head of metal tried (amounting to but a few inches) was too insignificant to yield any clear indication.

It has been proposed also in America, in order to obviate some of the evils of unequal cooling, in large guns during consolidation, to cast them hollow and cool, from the interior as well as exterior—by passing through the former a cooling current either of air or even of water.

The method has nominally been prescribed for the conduct of some of their government contracts for guns; but I have reason to believe that practically the device has been abandoned, and that, as most founders would have foreseen, the plan is too far removed from easy control, and too liable to produce evils greater than those it was intended to remedy, to be of any service. In fact, a cast-iron gun cooled down too fast from the interior will be in a far worse condition to resist the strains of service than one that has cooled from the exterior surface only.

Practical iron-founders are in the habit of judging of what they deem by experience the best temperature of the fluid iron for being poured into the mould, by a certain peculiarity in the form of the vorticose movements that go on upon the surface of a mass of fluid iron, and called technically "the breaking" of the iron. This test, however, is perfectly empirical and fallacious; the very lowest temperature at which the iron remains liquid enough fully to fill every cavity of the mould without risk of defect, is that at which a large casting, such as a heavy gun, ought to be poured. As respects the rapidity of cooling desirable, we shall be enabled presently to consider the conditions that determine the extent to which it may be safely carried.

A certain amount of contraction on becoming solid from the liquid state occurs in all castings. It is well known to practical founders that for cast iron this is variable, and depends upon the mass of the casting, being greatest for small, and least for large castings; but it is obvious, and it follows, from M. Bolley's researches, that the contraction also will be greater in proportion as the metal is poured into the mould at a higher temperature, although, from the expansion in the act of crystallising, the specific gravity of the solid mass may be less at the higher than at the lower temperature of "pouring."

As therefore there are two conditions that principally affect the degree of contraction, the total change of volume between the liquid metal and its solid casting, namely, the extent to which the fluid metal as entering the mould has been expanded by elevation of temperature, and the state of final aggregation of the crystalline particles, which we have seen depend much upon the former, so

there will be a determinate amount of contraction due to a determinate thickness or mass of casting, irrespective of, though also related to, the co-efficient of contraction for any particular "make" of iron; for there is no doubt that different makes, cæteris paribus, contract somewhat differently. From whence it follows that different parts of the same casting, if differing materially in scantling or mass, will have different amounts of final contraction; and hence—

> Sudden changes of form or of dimensions in the parts of cast iron guns, besides the injury they do to the crystalline structure of the mass, introduce violent strains, due to the unequal contraction of the adjoining parts, whose final contraction has been different.

How desirable is it, therefore, to introduce such changes into the forms of our ordnance as shall avoid those sudden and enormous (and often useless) changes of adjacent mass that we observe; as, for example, in the sea and land service, 13-inch mortars, where at the chamber the thickness of metal (where the strain is least) is nearly double that of the chase, and suddenly becomes so; a malconstruction, the full evils of which we have not now time to consider.

The amount of *lineal* contraction due to solidification of cast iron appears to vary with metal and circumstances of casting from $\frac{1}{120}$ up to $\frac{1}{90}$ of the dimensions of the cold mass. Its contraction in volume therefore (more than three times this, and probably not equal in the directions of three rectangular axes) is so great, and the difference such between its measure for large and small parts of the same casting, that its effects never should be neglected.

Its effects are well known to founders in causing castings of certain forms to become distorted, or spontaneously broken, after they have solidified. To multiply instances would be tedious, but one circumstance requires remark, as proving that these internal strains, occurring in castings of variable bulk, exist when little suspected, and that it is with extreme slowness that the molecules, after consolidation, appears gradually to assume changes of minute arrangement, and to adjust themselves within certain limits to a state of permanent equilibrium.

It is a fact known well to practical mechanics engaged in boring or turning, or otherwise cutting into large castings of iron that have

cooled safely and without crack or flaw, that yet, when a part of the whole mass shall have been cut away, as for example, when a large and thick-flanged cylinder, or a large-toothed wheel or other irregular discoid mass, is "bored out," the form of the exterior of the mass changes during the operation. The portion cut away destroys the temporary equilibrium that was established in the mass, and it again changes its form and perhaps its symmetry. For some most valuable illustrations of the singular forms or lines of direction which the curves of internal tension and compression take in solids of various forms thus under elastic constraint, Mr. Maxwell's paper, Trans. Royal Society, Edin. vol. xx. part I. may be consulted.

They bear a remarkable analogy to the nodal lines traced by the researches of Chladni and Savart in the vibrations of sonorous plates, and directly are connected with the optical properties first shown by Sir David Brewster in glass under constraining forces.

Sometimes a casting which has cooled safely will fly to pieces on receiving a sudden jar or blow of a trifling degree of force. A fact which is in analogy with that observed by Captain Parry in his earlier Arctic voyages, viz., that the astronomical instruments exposed to extremely low temperature for long periods and quite undisturbed, did not contract to their extreme points until after they had been subjected to some slight jar or blow, when the metal of the instrument *suddenly* became reduced in volume and its dimensions again stationary.

The extreme slowness with which these molecular changes take place, due to the gradual adjustment of such internal strains, has been beautifully shown by M. Savart, in a memoir on the Elastic Properties of Solids (Annales de Chemie, vol. xli. p. 61). He found that plates of sulphur cast into flat discs continued to change their state of molecular arrangement for long periods after solidification.

It follows from this that old guns that have long been bored and laid in store are likely to be more trustworthy than those hastily cast, bored out, and brought into service, and this seems to be supported by experience in some degree.

Let us now proceed to apply to *wrought iron* the law of molecular constitution already viewed in reference to cast iron; and then

briefly to draw one or two conclusions as to the proper methods of construction of wrought-iron guns.

When wrought iron in any of the usual forms of its manufacture is fractured, its molecular structure presents itself, more or less distinctly pronounced, in one or other of three forms:

1°. Its mass consists of minute crystals of nearly uniform size, whose facets present themselves at all possible angles, like that of refined sugar. This "saccaroid" structure usually belongs to the most highly refined iron, and often to hard steely irons, such as those of Sweden. The larger bars of Low Moor iron present perhaps the finest examples of this structure.

2°. The surface of fracture consists of large, sometimes very large, lamellar spangles or plates, the facets of crystalline cleavage, whose directions tend to coincidence generally with the surfaces of fracture. The number, size, and directions of these facets varies in the same mass with the directions of fracture. This is the structure of all large and heavy forgings or of *large* rolled bars. This and the former structure are often found irregularly united in the same surface of fracture in ill-manufactured iron, and is the usual one presented by common small bar iron.

3°. The fracture (hard to produce, owing to the greater flexibility of the iron than in either of the preceding cases) when effected, presents long parallel fibres, or baccillary crystals, running in the direction of the largest dimension of the bar. This is the structure of the best and toughest iron, such as that for making chains and rivets, good boiler plates, &c. It is found partially combined with the 1st and 2nd in some inferior irons.

We found in cast iron that the law of arrangement of its crystals is to place themselves perpendicularly to the surfaces of the mass. In wrought iron the tendency is, upon the whole, to place themselves parallel to the principal surfaces. It would seem, therefore, at first, that the law of aggregation, apparently so opposite, must depend upon totally different conditions; they are, however, essentially the same. *In wrought as in cast iron, the principal axes of the crystals*

tend to assume the directions of least pressure throughout the mass, while exposed to pressure and heat in progress of manufacture.

Let us take the most strictly normal structure, the 3rd; for example, a round bar of rivet iron half an inch in diameter. This has been formed by the pressure of the grooved rollers in directions transverse to the axis of the cylinder, pressing it smaller and smaller, and still elongating it from a short thick mass, whose original structure, if broken, may have been that of 1 or 2. The metal being rolled at a temperature at which it is as soft as lead at ordinary temperatures, heat is evolving the whole time, as in the case of cast iron in cooling; but the pressures introduced within the mass are of a different character, and arise from a different cause. In cast iron they arose from the contractions of the mass in cooling. In the wrought iron bar (relatively small in two of its dimensions, and therefore little affected at all by contraction in cooling), the internal pressures are produced by the rollers; but their pressures are all in directions perpendicular to the length of the bar, or, in our round bar, in the directions of the radii of the cylinder. The direction of least pressure is therefore coincident with the length of the bar, and this is the direction in which the principal axes of the crystals arrange themselves. The same is the case with iron drawn into wire, where the directions of maximum pressure being manifestly in the plane of the "drawplate," the aperture in which presses powerfully round the periphery of the solid passing through it, that of least pressure is, as before, parallel to the length of the wire, and so are the fibres or crystals arranged.

Heat, as increasing malleability and ductility, facilitates the arrangement; but as iron is a ductile substance even when cold, so heat is not essential to the molecular change in the arrangement of its particles; just as in cast iron we saw that molecular transpositions may continue long after the mass has become solid.

This is as strictly in analogy with the observable facts of crystallization in other bodies, whether simple or compound, ductile or rigid, passing through an intermediate plastic state, or crystallizing per saltum, which crystallizes in bacilliary or fasciculated crystals, as were the analogies we found in the case of cast iron. Thus, for example, arragonite, tourmaline, gypsum, actinolite, manganese,

alum (from Cape Coast Castle), amianthus, &c. &c., are all frequently found in embedded (more or less rounded) fasciculi, of long parallel fibrous crystals. When these are examined carefully with a lens, the external crystals are always found more or less deformed by the pressure of the external embedding matrix, to which they are moulded, although not formed by infiltration and gradual filling of a mould. In every such case there are accompanying evidences of great pressure in directions perpendicular to the longer dimensions of the baccillary mass. Thus nearly cylindric pencils of arragonite are found so formed in the intensely compressed chalk, overflowed by huge incumbent caps of basalt in the North of Ireland. Similar pencils are found, though not cylindric, of tourmaline, in granite, manganese alum, and fibrous gypsum, in enormously deep beds of clays, which, when soft and plastic, transmitted the pressure of their own mass of hundreds of feet in depth, with the fidelity almost of a fluid. Again, amianthus in serpentine, whose configurations prove the former play of enormous pressures, through plastic masses since become solid and rigid; and instances might be greatly multiplied.

Two of the examples given—arragonite and gypsum—present the remarkable identity, that they are found in both of two conditions, viz. in the arrangement of the crystals of cast-iron, with their principal axes perpendicular to the bounding planes, and parallel to them as now indicated for wrought iron; in each case the arrangement having followed the lines of least pressure, howsoever produced, provided it were coincident in time with such other conditions, whether of ductility, plasticity, fusion, or liquidity by solution, as admitted of molecular transfer and re-arrangement.

Returning now to the wrought-iron rolled bar, while its diameter continues small or moderate, although, in the progress of its cooling, internal strains and variable pressures are induced by contraction,—still, as almost all appreciable contraction is confined to the one direction of the bar's length, so these new internal pressures are inoperative in producing any distinct changes in the disposition given to the (fibre or) crystals in rolling. Not so, however, if the diameter of the bar, in place of being small, be very large in proportion to its length, and its mass great in proportion to the pressure brought upon it by the rollers. The operation of rolling is then less

effective in the first instance to induce a general and uniform parallel arrangement in length of the principal axes of the crystals; some remain in other directions to the bar's length: the bar, however, is now let to cool; fresh internal pressures become developed by contraction within its mass; the cooling goes on much more slowly, for the mass is much greater, in proportion to its surface, than in the long slender bar; and hence there is time for the new play of forces to act in re-arranging the crystals; the heat is carried off most rapidly from the greatest surfaces of the solid—but these are the sides of the bar. The contraction is greatest in the direction of its length; the maximum pressure due to contraction, therefore, coincides with the length of the bar; and more or less of the crystals arrange themselves now *transverse* to the length of the bar, in the directions of least pressure.

Whether the crystals of iron expand and contract by change of temperature alike in all axes is not known as yet; if not, and that the principal axes are those of greatest expansion and contraction, then, as the longitudinal contraction of the whole bar is proportionally greater than that in either of its other dimensions, so the previous longitudinal arrangement of the crystals, in so far as rolling has been operative in producing it, now increases the tendency to the secondary rearrangement of the crystals transverse to their former position. The small slender bar cooled almost instantly, and at once fixed the crystals and the longitudinal position they had assumed—length of time in cooling admits of the rearrangement in the heavy thick bar—aided by the softened condition of the mass as it passes gradually from a yellow heat to coldness.

Thus then as the mass—the relation of this to form and hence to surface—and of all, to the pressures transmitted to the iron in rolling, and to those induced subsequently by contraction in cooling, are varied, so will the main directions of crystalline arrangement be varied also; the variation may be either total and complete, as in the case of the slender bar, or partial and imperfect as in the grosser bar. But the evidences of ANY arrangement must depend upon the extent to which the individual crystals in any particular "make" of wrought iron are susceptible of development; in the case of *very* highly-refined iron (in the language of the iron-master "over-wrought" iron, in which

there has been no "cinder" left), with all its carbon perfectly combined, and thus approaching to steel, the crystals are so minute, often so perfectly microscopic, that in large bars no other than the uniform "saccaroid" structure is discernible, though the fibrous becomes perfectly developed in any small ones. This is the case with the fine Low Moor iron, which in rolled bars of 2 inches diameter and upwards presents a fracture almost identical with that of cast steel, but in rivet-rods a fine fibrous one.

I have used the term "fibre" as being already long in use, and conveying well to the eye the character of this particular form of crystallisation. But it should be clearly understood that the "fibre" of the toughest and best iron is nothing more than the *crystalline arrangement* of inorganic matter, and that the false analogies continually used, in which such fibre is spoken of and reasoned upon as identical with that of organic bodies, such as wood, hemp, &c. have no reality or basis in nature, and only tend to mislead.

The principles upon which the developement in size of individual crystal depends, however, will be best understood when we have considered some of the effects on wrought iron of forging into great masses.

In *rolled* bars, which we have so far alone treated of, the pressure of the rolls, unaccompanied by impact, though conveyed only to the one point of the bar at a time, is in succession and with great uniformity of direction applied to every part of it; moreover, the intensity of the pressure upon the unit of surface, or in relation to the section of the bar, steadily increases as the latter diminishes in size at each successive passage through the rolls.

A very different set of conditions occurs, however, in a *forged* bar or mass. The whole of the pressures now are impacts suddenly applied to local points of the surface, and thereby unequally transmitted through the ductile or partially ductile heated metal to its interior. The pressure at the surface due to any blow measured in the time of the hammer's descent through the space through which the surface before the blow has descended, is rapidly lost in transmission within the mass, by inertia, and by the corpuscular forces of whatever sort that the substance of the heated iron opposes to change of form. Blow follows blow in continually changing directions, and

on various portions of the mass. The directions of maximum pressure within it as constantly change as do the intensity of these pressures, not only in depth, but as transferred from point to point struck; the elasticity of the metal (though no doubt of a different sort from its elasticity when cold and more perfectly a solid) still exists, but in the various parts of the mass kept during the hammering, and perhaps for long after, in a state of instability. The lines of least pressure, therefore, are constantly changing under all these varying causes, and with them the directions of the principal axes of the crystals become changed and changed again—perturbed, broken, and confused; and if the mass be sufficiently large, when cold, and after its forging has been completed, its fracture, however fine and good the wrought iron, presents nothing but a confused mass of small crystalline facets differing scarcely at all from the appearance of cast iron in moderately large castings.

Yet no change other than that of molecular arrangement has necessarily occurred in the large mass, for it is a fact that such a confusedly crystallised mass may be built and "faggoted up" from small rolled bars, each of which is previously perfectly and uniformly fibrous, that they lose their fibrous structure and assume the confusedly crystalline one in the process of being united by forging into one large mass, and that a portion broken or cut off from the mass may be again rolled down into small bars, which shall be as fibrous in structure as at first.

The developement in size of crystal varies with the particular sort of iron. It appears to be largest and most lamellar (in large masses) in the most highly refined iron, and which contains an unusual dose of silicium; but the relations of size of crystal to chemical constitution require much further examination. With the same iron and same volume of forging, however, the size of crystal appears to be developed larger, in proportion to the time that the mass is maintained hot and in process of forging. This time is necessarily greater as the mass is so, and as the operations of reducing it to required form are more complex or laborious. In fact, as in cast iron we saw that the crystals were larger the longer the mass required to cool, so in wrought iron they are larger the longer it is kept hot. And thus it happens that in very large and

massive forgings, requiring often to be maintained at temperatures varying from a welding heat down to dull redness perhaps for weeks, crystals are developed within the mass of a size materially to diminish the cohesion of the iron in some places where flat planes of crystalline cleavage produce partial "planes of weakness." The size of these crystals is occasionally surprising, the broadest and flattest planes of cleavage frequently running in the directions in which surfaces of the integral "slabs" or portions of iron of which the mass has been formed have been welded together. The author has observed crystals so posited presenting flat planes as large as the surface of a half-crown piece.

The elasticity of wrought iron is greatest in the direction of the principal crystalline axis. Some experiments of Mr. Fairbairn's on the relative ultimate resistance to rupture of boiler-plates, when strained in the direction of their fibre, *i.e.* in the direction in which they were rolled, and transversly to the same, have induced him to come to the conclusion that there is little, if any, difference in either direction. If the iron of the plates be so very harsh, rigid, and bad of quality, as to have *no* (fibre) longitudinal crystalline arrangement, but approach nearly to that of a slab of cast iron, this may perhaps be nearly true, but in plates or bars of good quality it is certainly erroneous. The very few experiments upon which Mr. Fairbairn's conclusion rests will not even warrant it, if *one* result, contrary to all the others, and so exceptional as to suggest the probability of an error, be abstracted from the average deduced from the remaining ones; and it seems wholly disproved by the experiments of Mr. Edwin Clarke (Britannia Bridge, vol. i. p. 377), who found that bars cut longitudinally and transversely from the same plate of fine fibrous iron of excellent quality, were broken by strains per square inch of section of—

	Tons.		Tons.
In the direction of the fibre . .	19·66	to	20·2
Across the fibre	16·93	to	16·7

and that *the ultimate extension of the plate in the line of the fibre was double as great as transverse to it.*

Taking the means of these experiments then at 20 tons longi-

tudinal, and 17 tons transverse, the value of the coefficient T_r* in each case will be—

In the line of fibre	. . . . =	234·84
Across the fibre	. . . . =	30·47

Taking the total extension = ·0016 in the first, and half that in the second.

We find, therefore, that the elastic range of wrought iron of any given quality depends upon the direction of the crystalline axes in relation to the strain, and that the elasticity is a maximum in the direction of the principal axis of the crystals, or line of fibre; and the important deduction arises from the above, that, for artillery purposes, the ultimate strength of a gun, in which the explosive strains are all resisted by wrought iron acting in the line of fibre, is to that of one acting transversely to the same, as 234·84 is to 30·47, or about as $7\frac{1}{3}$ to 1. This ratio expresses in fact the relative strengths of a "twist barrel" and of a common "skelp-welded" or longitudinally welded one; but almost the whole advantage of this is lost in massive forgings.

We have found that the effect of large increase in the mass of wrought iron is to prevent any regular or uniform arrangement of its integral crystals by the process of manufacture. That as such masses are necessarily continued long heated while forging, and occupy long in cooling, and contract considerably in all their dimensions in cooling, so the crystals are developed to a large size, and become arranged to a greater or less extent in directions transverse to the surfaces of contour of the mass. The results are irregular "planes of weakness," reduction of ultimate strength to resist a quietly and steadily applied tensile force of from 20 to 17, and reduction of resisting power to such impulsive forces as are concerned with artillery, in the ratio of from $7\frac{1}{3}$ to 1, or probably even more; for a train of difficulties is introduced in the manufacture, and of injuries done to the chemical qualities of the material, in a rapidly increasing proportion as we continue to increase the magnitude of the mass to be forged.

When the mass exceeds a very limited bulk (in breadth and

* Poncelet's coefficient of "vis viva of rupture."

thickness) the processes of rolling, &c. are at an end. Those of forging by the tilt or steam hammer alone are available; skilled labour, and all the mishaps to which the results of the most adroit workmanship are exposed in dealing with the heating and hammering of vast and scarce manageable masses, are inevitable. The mass must be gradually built up and aggrandized in size, by continual welding on to it of small pieces, involving reiterated heating and partial cooling, exposure for weeks perhaps to a temperature at which the exterior of the mass gets changed more or less in chemical constitution, and at each welding the risk of inclusion of more or less slag, cinder, or other foreign matter. At every additional piece thus laid on by welding, an additional doubt is produced as to whether or not the weld be sound throughout; no examination at the time can with certainty decide this: the mass however grows continually in bulk and weight, the inertia of the hammer (large and powerful as this has become through the intervention of the direct action of steam) becomes reduced in relation to that of the mass in the same ratio, the blow no longer acts with uniformity upon the mass submitted to it, but is confined in immediate effect nearly to the point struck. The mass, if very large, and especially if also long, can no longer be all maintained hot, but the jar and shattering vibration of every blow, as it thunders down upon the huge piece, continues to be transferred to the crystalline particles of the colder or quite cold portions, and probably produces at length some considerable alteration of molecular arrangement, in deterioration of strength.

At length the limit is reached when with our present known modes of working wrought iron (even with the heaviest and best appliances) we can no longer add to its size. The limit is reached by the power of heating the mass, or a certain required part of it, to the welding heat. The time required for the piece to remain in the furnace to effect this continually increases as its bulk grows, and with it the sources through which heat is lost and dissipated; but a certain proportion of iron is burnt away or melted off from the surface at the part requiring to be brought to welding heat and from adjacent portions at every moment that it remains in the furnace; at last as much in weight is burnt off or lost at each welding as equals the weight of the "slab" or mass laid on, and the labour is

then in vain. The work, like the embroidery of Penelope, becomes an endless task, and the limit has been reached beyond which the piece can be forged no bigger.

This limit can be stretched a good deal by the extreme skill of the operative forgeman and by the skilful construction of his furnace; but, however great these may be, this limit is at length reached by all, and with our existing tools in Great Britain is probably reached in every case at a diameter (of a cylindrical mass) of about four feet and about twenty feet in length.*

To the unpractised observer, who looks at one of these ponderous masses withdrawn from the furnace glowing like a sun, and observes the apparently little effect upon it that the thundering blows dealt by the steam-hammer produce, it always seems that nothing more is demanded than great increase of weight and length of stroke, or increased power in the hammer. This however is a mistake; good forging in heavy masses depends not so much upon the force of the blow as upon its exact direction, and its application at the precise moment when the welding metal is fit to receive it. The only effect of great increase in the power and especially in the velocity of the blow is to shatter and dislocate the internal or adjacent portions of the mass which are at or about, a low (cherry) red heat, at which temperature the best wrought iron appears to lose much of its plasticity of heat, and be comparatively crumbling and brittle. In fact, with existing hammers of five tons weight and six foot blow, this effect is actually produced very frequently.

Another and very different cause of unsoundness in very large forgings of great diameter I have recently observed the conditions of with care and explained elsewhere. It arises from the fact that in the slow cooling of such a mass the exterior becomes cold and rigid while the interior is still soft and even above a red heat. When finally the latter cools to the point of rigidity violent cross strains, owing to complex play of contractile forces (which time forbids my

* I am aware that these "difficulties of heavy forging," though undeniable, are attempted to be made very light of by a recent writer of one of the articles on "The Useful Metals" in Orr's Circle of the Sciences. The able and intelligent manager of the Mersey Steel and Iron Company's forge will, I trust, pardon my saying that his opinion cannot be considered unbiassed upon such a subject.

here entering upon), are produced, and the interior of the mass tears itself asunder, irregularly, but in a general plane passing through the axis and parallel to it, if it be a cylinder or prism, and reaching across about half its diameter. This defect is not visible until the mass be cut transversely. This is the main cause of the almost constant want of soundness in nearly all large forgings.

If we are to look for future great extensions of our power of producing vast masses of malleable iron (for whatever purposes) that shall give greater assurance of internal soundness, and preserve in the large, all the qualities of uniform and determinate disposition of fibre—in a word, all the valuable qualities of the best wrought iron as now known in small bars, it must be by some great extensions or modifications of the rolling process, accompanied by such improvements in the furnaces and modes of heating as will enable the largest masses of prismatic form to be produced out of more slender rolled bars laid together and heated, and at one welding operation rolled together (or otherwise pressed at successive points) into one gigantic bar, which for artillery might be then twisted by suitable machinery, such as that patented by Melling. To the subsequent operations of bending, cutting, or shaping such prismatic masses however, so as to fit them on a larger scale for the many general purposes to which forged pieces, or "uses" as they are called, are now applied, narrow limits of practical disadvantage and difficulty can be foreseen; and as regards the fabrication of artillery it scarcely admits of doubt that the limit of useful size has been already far surpassed, and that it is to a skilful and judicious combination of parts, each formed of malleable iron of moderate and manageable dimensions, rather than to forging in one huge piece, that we should look for the production of guns of the largest class in this material.

Those who desire to enter upon the consideration of the best modes of attempting this, I must refer to the pages of my own work upon the construction of artillery, as well as to those of others who have proposed various constructions of compound or built-up guns. The subject is too large, and involves too many dynamic questions of an abstruse character, besides those physical ones of which we have been treating, to be entered upon now.

I cannot leave the subject of molecular constitution in wrought

iron however, without explaining one most interesting case in which the law of aggregation before enunciated, throws a flood of light upon a hitherto ill-understood and obscure class of phenomena, namely, upon *the change of crystalline axis in wrought iron cold*—that is to say, at ordinary temperatures; that change by which, without sensible heating or cooling, without fusion or change of external appearance, and often with little change of form or volume, a piece of wrought iron, before tough, flexible, and "fibrous," may be made to become instantly harsh, rigid, crystalline in fracture, and brittle. This is the change by which it has been *assumed* that railway axles, shafts, chain-cables, &c., and other articles of tough fibrous iron, grow brittle and faithless while in use.

Much has been loosely written of late years on this supposed "loss of fibre" and change to a confusedly crystalline structure in wrought iron, by the mere effects of long-continued jarring or vibration, or of very slight bending to and fro at ordinary temperatures; many affirming stoutly the fact, but without bringing forward any instance that amounts to proof; and others denying it, asserting in explanation, that in the instances adduced the "crystalline iron was never fibrous," and which is probably the fact in most of the cases adduced.

The subject is one still requiring, for its being fully understood, a very careful and difficult research, and one worthy of being at once made. The following conclusions may however he provisionally offered, as probably not very incorrect:—

1°. There seems no reason to believe that any extensions or compressions, and therefore any flexures, however long continued or often repeated, produce any molecular change whatever in wrought iron; provided that—

a. The range of extension or compression be *far within* the elastic limits.

b. That the velocity with which the extension or compression is made be not extremely great, *i. e.* not beyond the "pulse period," due to the elasticity of the material.

2°. Nor any reason to suppose that jarring or vibration, if unaccompanied by permanent change of form in the mass, is capable of effecting any molecular change whatever, provided that the material shall have been previously in a state

of molecular repose, *i.e.* free from internal strains due to form, contraction on cooling, &c.

Nor is it probable that abrasion, such as the grinding away of the bearings of railway axles, or the scoring and rifling of the chase of a wrought-iron gun by the passage of the shot, produces any molecular change; but—

3°. It does appear certain, from many well-observed phenomena, that instantaneous changes of molecular structure, and reversals or transpositions of the crystalline axes, can be produced in wrought iron at ordinary temperature, by the violent application of mechanical force, producing change of form at one or more points of the surface of the mass, if the directions of the force and the extent of change of form be such as to produce internal strains and inequalities of pressure, and that the extent of these latter is greater than the resistance in any one direction, due to the elasticity and range of the material.

It would be foreign to our subject to pursue this here at any great length, however interesting and important, and with one familiar instance we must dismiss it.

The well-known operation by which a blacksmith "breaks cold, over his anvil," a bar of the toughest iron that can be had, consists in "nicking" one or both opposite sides of the bar at the required point of its length, to a *very small* depth, with a chisel having an edge formed to a very obtuse angle generally about 90°, and driven into the substance of the bar by blows from a sledge with great velocity. When this is done, a bar of moderate size, tough, fibrous, and at every other place capable of being bent sharply double without fracture, may be broken across at the "nicked" place often by bending over one's knee, but always by a few light blows transversely on the anvil.

When the fracture is exposed, it is found at the "nick" to be short and crystaline; the crystals are, on the whole, arranged transversely at this point to the bar's length; their facets are largest and most transverse, just at the bottom of the angle of the nick; and either no sign of the fibre constituting the structure of every other part of the bar is visible, or occasionally some portion of the section at the side or part most remote from the nick is still visible.

Now what happens here is rendered obvious by the diagram in Plate III., in which fig. 1 represents the side of such a bar at the "nicked" place, and the change of direction there of the crystalline axes. But what internal forces have acted on them? Looking at fig. 2, it will be seen that driving into the substance of the bar the edge of the wedge-shaped chisel, has produced compressions; but the pressures are propagated in directions perpendicular to the faces of the wedge, or of the nick that is the express copy of it. These pressures in the directions *a b*, *a′ b′*, are resisted and finally equilibrated by the elastic compression of the crystals in the directions of their principal axes (mainly) *c b*, *c′ b′*, and the resultants of these mutual pressures meet in the substance of the bar, in the directions *b n*, *b′m*, which are those of maximum internal strain; therefore in the space between these, and approaching the angle of the nick, and perpendicular to the resultants, are the lines of minimum pressure. Now these are the new directions that the principal axes of the crystals assume at the moment that these pressures disturb their previous equilibrium; that is to say, at the moment of making the nick.

Fig. 3 shews the further change in crystalline arrangement assumed by the bar, after that above described as due to the "nick," and which is produced by the subsequent bending prior to final fracture.

Supposing the bar bent by pressure or blows towards the side remote from the nick, as soon as the fracture is complete it presents a surface as in fig. 5, consisting of facetted crystals piercing the bar transversely from the angle of the nick to a certain depth—a central portion where the original longitudinal fibre of the bar has remained unchanged but is broken across—and again a narrow strip of flat facetted crystals at the side furthest from the nick transverse to the line of fibre. Now these latter were produced by the bending of the bar after the nick had produced the former. The side furthest from the nick is the *compressed* side of the bar, the neutral line being somewhere between. *The direction of least pressure* at this compressed side is therefore *transverse to the length of the bar*, and hence the new direction taken up by the crystals here in accordance with the general law. Had the bar been bent towards the side nicked in place of the opposite way, the nicked side would have been the compressed side, where the transverse crystals were already formed, and the fracture when

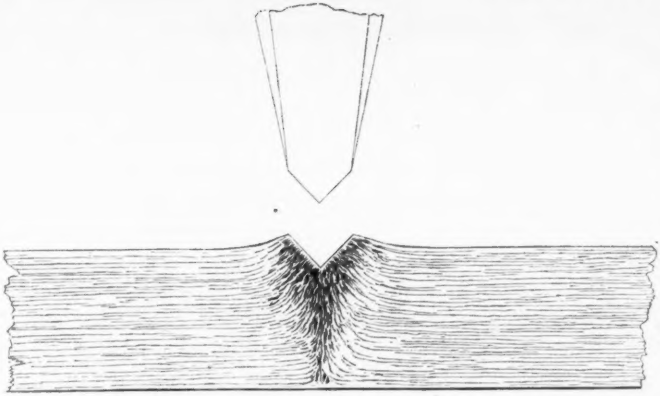


Fig. 1.

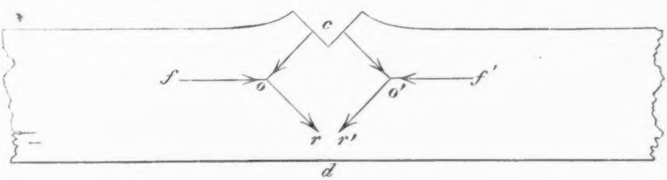


Fig. 2.

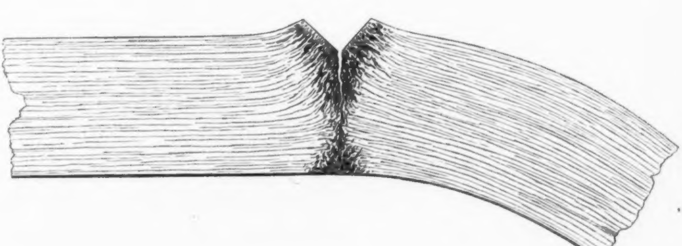


Fig. 3.

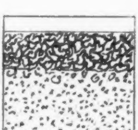


Fig. 4.

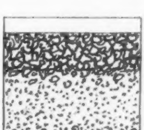


Fig. 5.

CHANGE OF STRUCTURE IN WROUGHT IRON, COLD.

broken across would have been fibrous out to the very edge remote from the nick (provided the whole bar had been uniformly fibrous beforehand), as shewn in fig. 4.

Thus then this change of crystalline arrangement is only another case of our general crystalline law—that the principal axes are found in the directions of least pressure within the mass, and that the change of direction possible to be produced in "cold iron" is due to the fact of its having more or less ductility at all temperatures, which means, in fact, that more or less permanent displacement of molecules is possible in the material at any temperature.

There is therefore no ground for assuming that wrought iron artillery would rapidly or at all (if originally properly proportioned) deteriorate in tenacity, and so gradually and yet unascertainably become unsafe in service.

Mr. Nasmyth, Mr. Hood, and Mr. Thorneycroft have written on this subject; the latter has collected some interesting facts, though some seem rather warped by preconceived views. In no paper, however, that the author has seen is any attempt made to connect all the phenomena of change of crystalline structure in iron at all temperatures with the action of some one recognisable force, such as that which the author believes to constitute the true solution and key to all the varied and complex cases noticeable, and which he has been the first to enunciate, namely, *the assumption by the principal axes of the crystals of the lines of minimum pressure within the mass.*

In concluding this second head of the three into which I have divided the subject of my lecture this evening, I would wish to be understood, that I do not advocate the indiscriminate adoption of built-up guns of wrought iron, nor even the indiscriminate use of wrought-iron guns at all. I do consider, and my conclusion has been come to after a lengthened and careful investigation of the subject, and the endeavour to apprehend and attach due weight to the purely military aspects of the matter and the opinions of artillery officers, that the adoption of wrought iron as a material for field artillery would be attended with the most important results. Some of these, chiefly those relating to financial economy, durability, and the facility and economy of transport in service, may be learned by an inspection of the following tables, in which the results of much

patient research are condensed, and which appear to me conclusive in support of the value of wrought iron for this particular arm.

Wrought-iron field-guns, however, are readily within our grasp to form, soundly, simply, and with cheapness, by methods which I have elsewhere pointed out, in one piece, up to 18 or perhaps even to 24 pounders at least; and as assuredly the rifle principle will ere very long be successfully applied to field artillery (and so its predominance over the rifled musket again asserted), so it is not likely that larger calibres than these, if even so large, will be ever demanded for field-service.

TABLE I.

Of the Physical Properties of the principal Materials of Construction for Artillery, from British Data.

1	2	3	4	5	6	7	8	9
No.	MATERIAL.	Ultimate Resistance to		Immediate Resistance within Elastic Limit		Mean Extension per ton per square inch within	Mean Compression per ton per square inch within	Final Extension at the Elastic Limit
		Tension.	Compression.	Tension.	Compression.	Limit of Col. 5 in terms of L.	Limit of Col. 6 in terms of L.	In terms of L.
		Tons.	Tons.	Tons.	Tons.			
1	Gun-Metal . .	16	12 ?	4·5	3 ?	·000230	?	·00104
2	Cast-Iron . .	10	45	4·0	20 ?	·000220	·00018	·00088
3	Wrought-Iron	27	16	12·0	12	·000100	·00010	·00120
4	Steel	49	60 ?	16·0	17·5 ?	·0000375	?	·00060

		10	11	12	13	14	15	16
No.	MATERIAL.	Modulus of Elasticity.	Modulus of Elasticity e	Coefficient of *vis viva* of Elastic Resistance T_e.		Coefficient of *vis viva* of Rupture T_r.		Modulus of Force Transmission.
		L_e	In Pounds per square inch.	Tension.	Compression.	Tension.	Compression.	Feet per second.
		Feet.	lbs.	Dynams.	Dynams.	Dynams.	Dynams.	Feet.
1	Gun-Metal . .	2,790,000	9,873,000	5·24	?	65·94	?	8260
2	Cast-Iron . .	5,750,000	18,400,000	3·94	80·64	24·64	110·88	11100
3	Wrought-Iron	7,550,000	24,920,000	16·13	16·13	81·64	48·40	12083
4	Steel	8,530,000	29,000,000	10·75	?	92·55	113·33 ?	14108

NOTE.—The moduli of Elasticity are Tredgold's. The values of i, from the means of various experimenters, as also the values of columns 3, 4, 5, and 6.

TABLE II.

Comparison of Weight, Strength, Extensibility, and Stiffness; Cast-Iron being unity, within practical limits, to Static Forces only.

Material.	Weight for = volume.	Strength.	Extensibility.	Stiffness.	Torsion. Resistance.
Cast-Iron . . .	1·00	1·00	1·00	1·00	1·00
Gun-Metal . .	1·18	0·65	1·27	0·53	0·55
Wrought-Iron .	1·07	3·00	0·45	2·20	1·11
Steel	1·07	4·75	0·32	3·15	2·11

The torsion from Colomb and Tredgold's results.

TABLE III.

Molecular Properties of the principal Materials for the Construction of Artillery.

1	2	3	4	5	6	7
No.	Material.	Chemical Constitution.	Specific Gravity.	Relative Torsion of Rupture.	Temperature of Maximum Strength.	Coefficient of Expansion for 150° Fahr.
			Mean.	Degrees.		
1	Gun-Metal .	$Cu_{17}+Sn$	8·450	367°	32°	·001816
2	Cast-Iron . .	Fe.C+C′+m	7·200	52° ?	300° ?	·000893
3	Wrought-Iron	Fe.C+m	7·750	330°	360°	·000984
4	Steel . . .	Fe.C	7·800	200°	?	·001225

		8	9	10	11	12
No.	Material.	Specific Heat.	Coefficient of Conduction for Heat.	Relative Hardness.	Relative Resistance to Abrasion.	Relative Oxidation in Moist Air.
			?	?	?	
1	Gun-Metal .	0·110	236 ?	5	10·5	·10 ?
2	Cast-Iron . .	0·134	100	10	39·4	·42
3	Wrought-Iron	0·109	110 ?	20	322·6	·54
4	Steel . . .	0·109 ?	100 ?	40 \	968·4	·56

Col. 11, = hardness × T_e. ?

Col. 12, from the Author's experiments, Trans. Brit. Ass.

TABLE IV.

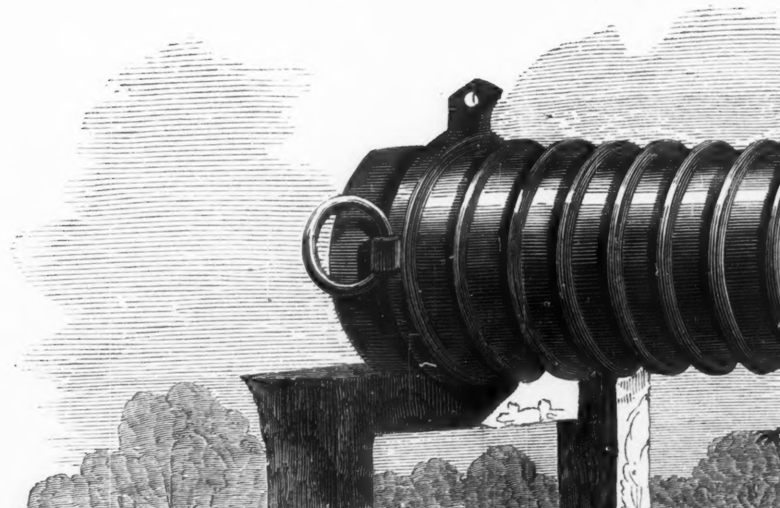
Comparative Financial Relations of the principal Materials of Construction for Artillery.

1	2	3	4	5	6
No.	Material.	Average Cost per Ton in Guns in England.	Relative Section for equal strength.	Relative Weight for equal strength.	Relative Money Value for equal strength.
		£			
1	Gun-Metal . .	160	1·60	1·880	5·33
2	Cast-Iron . . .	30	1·00	1·000	1·00
3	Wrought-Iron .	60	0·33	0·354	2·00
4	Steel	180	0·21	0·226	6·00

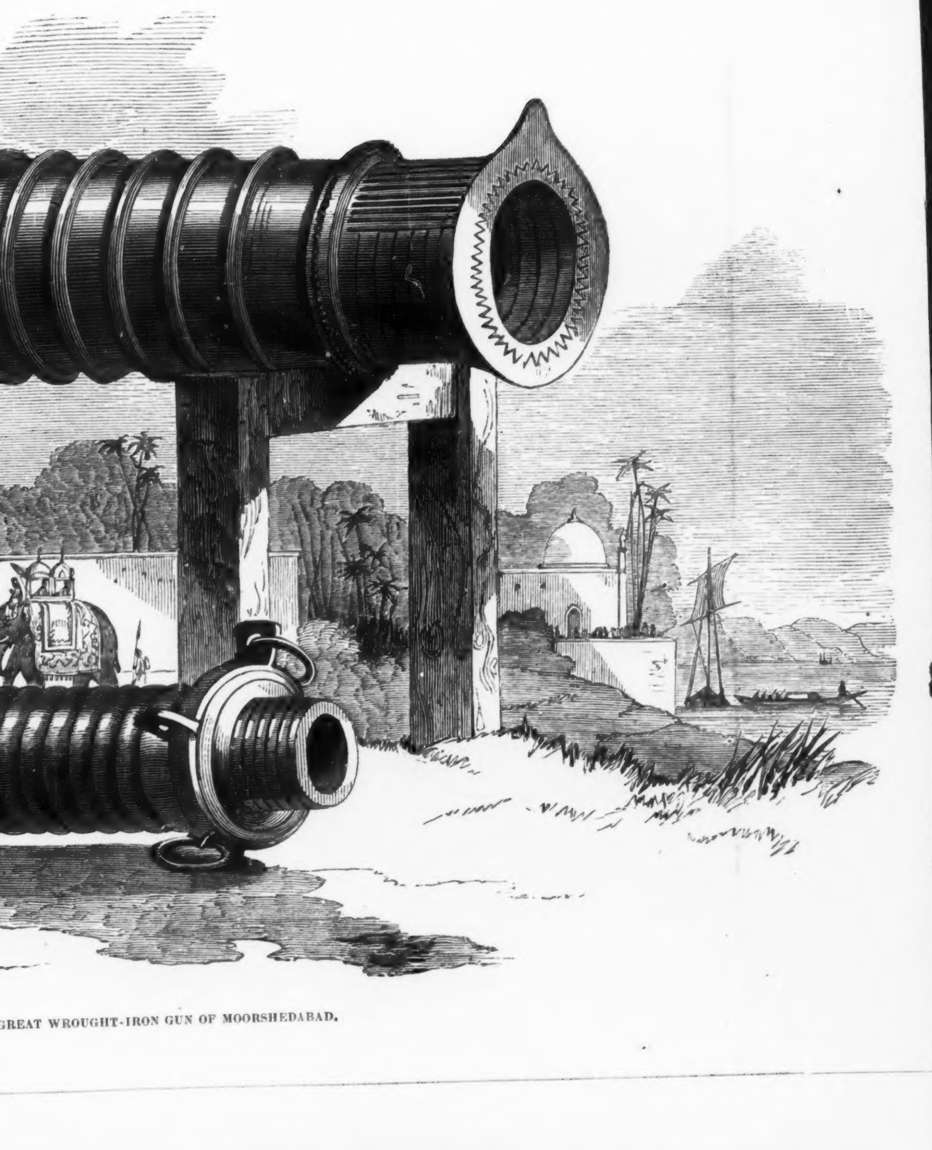
		7	8	9	10	11
No.	Material.	Relative Money Value for equal weights.	Relative Durability in Service where never overstrained.	Unserviceable value as old Material per Ton.	Loss per Ton on the first cost.	Relative Costliness, Capital and Durability included.
				£	£	
1	Gun-Metal . .	10·02	4	60	100	251·00
2	Cast-Iron . .	1·00	1	4	26	100·00
3	Wrought-Iron .	0·70	22	6	54	3·25
4	Steel	1·36	156	15	165	0·87

NOTE.—Cast-Iron is taken as unity throughout.
The relative strength is as opposed to static forces.
The relative durability takes account only of abrasion and corrosion.
Col. 10 = col. 6 × reciprocal of col. 8.

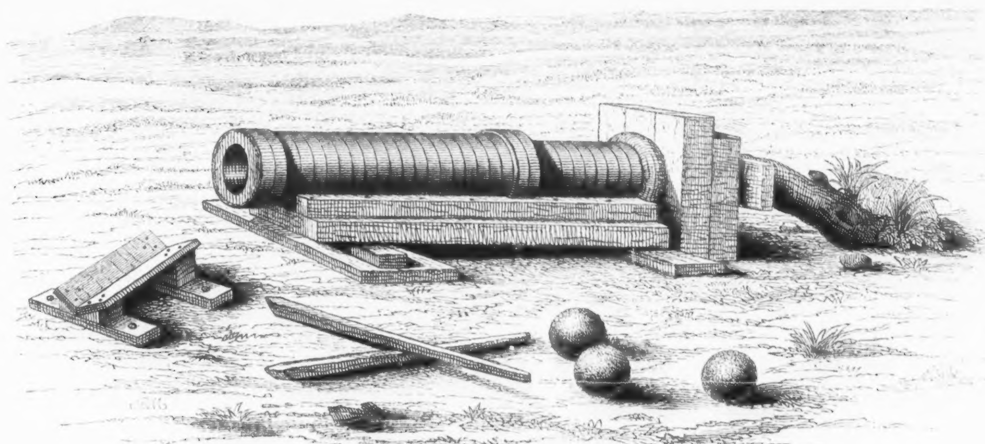
When we advance from the small calibres of field-guns to those already demanded for garrison and siege purposes, and to the still larger calibres that the most modern uses of stone and iron in fortification, in or out of connection with earthwork, have now demanded, it is obvious that we *must* resort to wrought iron as the material for our immense artillery, and that we *must apply this material in such a form as shall develope its best strength and powers of resistance, and according to methods the cheapest and the most certain in manufacture.*



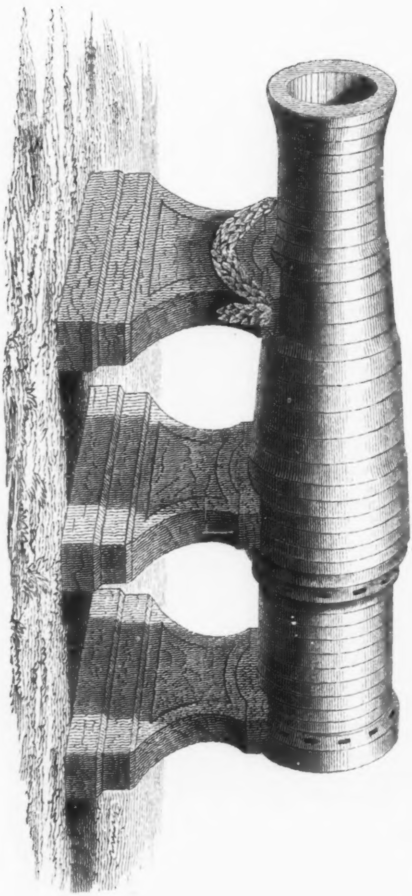
THE GREAT WROUGHT-



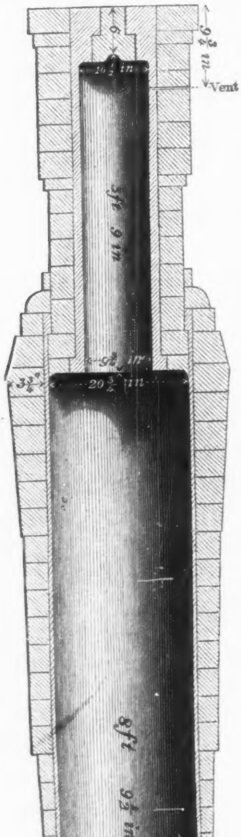
GREAT WROUGHT-IRON GUN OF MOORSHEDABAD.



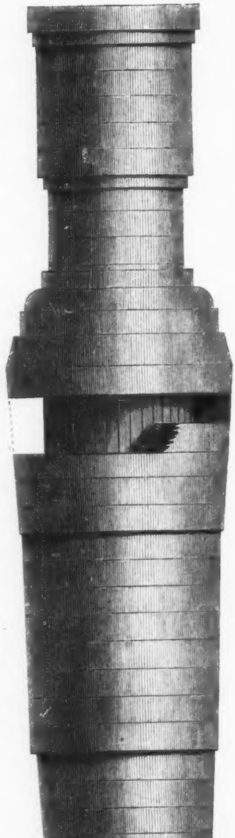
BOMBARD ON BED.



GREAT BOMBARD OF GHENT.



MONS MEG, EDINBURGH CASTLE.—LONGITUDINAL SECTION.



MONS MEG, EDINBURGH CASTLE.—EXTERNAL ELEVATION.

These methods develope themselves in the form of built-up guns, a construction the germ of which is very ancient, as may be seen in the drawings which I am enabled to exhibit of some ancient bombards of wrought iron, viz. the Mons Meg at Edinburgh Castle, the great bombard of Ghent, and, probably most ancient of all, the great bombard at Moorshedabad in Bengal. (Plates IV. V. VI. and VII.)

The built-up principle was adopted in these pieces of great calibre, not from choice unquestionably, but because the imperfect methods of iron manufacture of those remote times left no option to their constructors. They acted without any accurate theoretic knowledge of the strains they desired to resist, or of the properties and measure of passive resistance, of the material they employed. Accident, however, compelled them to a structure in great part theoretically correct, so far as it was carried, but the immense mechanical advantages of the *superposition of hooped plies* was unknown to the makers of the ancient bombards, indeed theoretically unknown until very recently.* Yet if such powers of resistance, as we know the middle age kamerlicks and bombards to have had, were obtained by untaught craftsmen, and with the feeble tools and defective metals of their days, may we not anticipate much from exact science and the marvellous powers of modern tools, when moving together in advance upon the same road that led to these ancient successful attempts?

To recapitulate then some of the advantages which the method of built-up wrought iron guns offers, they are, as respects the material itself—

1°. The iron constituting the integrant parts is all in moderate sized, straight prismatic pieces, formed of rolled bars only; hence, with the fibre all longitudinal, perfectly uniform, and its extensibility the greatest possible, and in the same direction in which it is to be strained, it is therefore a better material than any forged iron can ever by possibility be made.

2°. The limitation of manufacture of the iron thus to rolling, and the dispensing with all massive forgings, ensures absolute soundness and uniformity of properties in the material.

3°. The limited size of each integrant part, and the mode of

* See Mallet on the Physical Conditions involved in the Construction of Artillery. 4to. 1855. Notes.

preparation and combination, afford unavoidable tests of soundness and of perfect workmanship, step by step, for every portion of the whole. Unknown, or wilfully concealed, defects are impossible.

4°. Facility of execution by ordinary tools, and under easily obtained conditions, and without the necessity either for peculiarly skilled labour on the part of "heavy forgemen" or for steam or other hammers, &c. of unusual power, and very doubtful utility; and hence very considerable reduction in cost as compared with wrought iron artillery forged in mass.

5°. Facility of transport, by reduction of weight, as compared with solid guns of the same or of any other known material.

And as respects the mode of application—

6°. A better material than massive forged iron, is much more scientifically and advantageously applied; the same section of iron doing much more resisting work, as applied in the gun built up in compressed and extended plies, than in any solid or other gun.

7°. The introduction thus into cannon of a principle of elasticity, or rather of elastic range (as in a carriage spring, divided into a number of superimposed leaves), greater than that due to the modulus of elasticity of the material itself, and so acting by distribution of the maximum effort of the explosion, upon the rings successively recipient of the strain, during the time of the ball's traject through the chase, as materially to relieve its effects upon the gun.

In a word, we secure better material and apply it better. It is upon these principles that I have designed for Government the great thirty-six inch mortars, to throw a shell of a yard in diameter, and weighing in flight above 3000 pounds, which are now nearly completed.

Had time permitted, I proposed, under the third and last head of our subject, to have considered the effects upon cannon, of another class of molecular forces, namely, those due to expansion by heat in service, and especially to have shown the enormously increased strains produced on cannon, both in very rapid firing and in firing

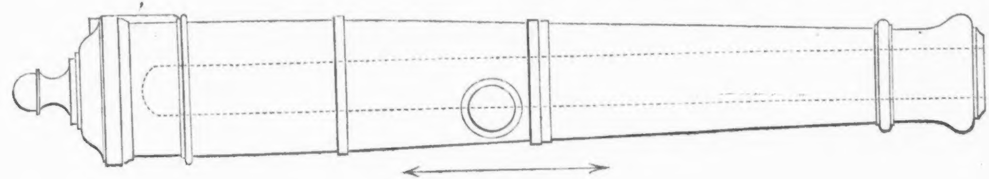


Fig. 1.

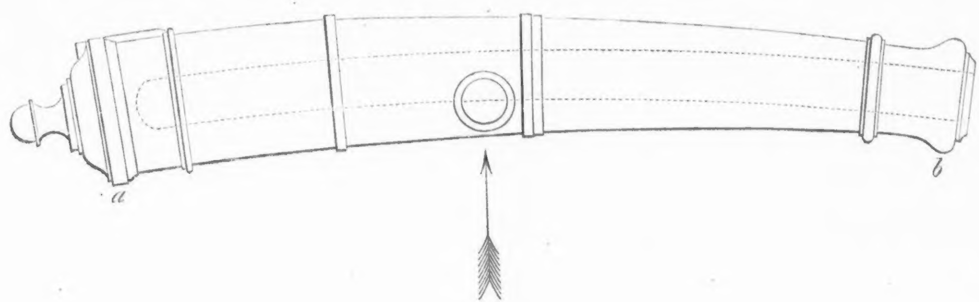


Fig. 2.

DROOPING AT THE MUZZLE IN BRONZE GUNS.

red-hot shot, by the unequal expansion of the interior and exterior of the gun; the more expanded interior producing a powerful splitting strain upon the exterior, independent of and before the application of the expansive effort of the exploded charge; and, again, to have pointed out the true solution of the long well-known phenomena, especially in heavy bronze guns, occurring after rapid and sustained firing, known as "drooping at the muzzle."

I can at this late hour, however, only venture to enunciate merely, that "drooping at the muzzle" is not due, as commonly asserted, to softening of the bronze gun by heat, and its becoming then bent by its own weight, but that it arises from the conjoint effect, of longitudinal expansion of the gun by the heat of repeated discharges, and the *relatively greater cooling* of the lower half of the gun by the continual *evection* of heat from its lower side, due to the ascent of the currents of atmospheric air which reach the gun, become heated by it, ascend as they become lighter than the surrounding colder air, and so carry off heat faster from the lower than from the upper side of the gun. This is true whether the gun be in still air or in a current of wind transverse to its axis, the chief difference being, that in the latter case, the gun is distorted more or less laterally as well as in the vertical plane. The play of forces producing this somewhat curious train of effects will, I trust, be easily understood by referring merely to the diagram exhibited. (Plate VIII.)

For a more full investigation of the whole subject of the effects of expansion by heat upon guns in service, I must again refer to my work "On the Physical Conditions involved in the Construction of Artillery," where I have shewn *how much* superior in this respect, as in all others, wrought and even cast iron are to bronze as materials for ordnance.

Perhaps at a future time I may be enabled to lay before the Members of the United Service Institution some of the grounds upon which I consider that cast steel, which has had a good deal of popular and ill-thought-out advocacy, latterly bestowed upon it, is an unsuitable material for cannon; indeed, some of these grounds may be gathered from the four comparative tables of the properties of the constructive materials for ordnance which I have had the honour to present to the Institution this evening.

Note—On the MOLECULAR CONSTITUTION of SOLIDS.

THE law of crystalline arrangement in crystallised masses, which passes as a clue of illustration throughout this Lecture, would demand a separate work, to treat it as its important relations to many of the most interesting questions of physics, and its enunciation, with clearness, would deserve.

To fulfil this in a note is impossible; a few remarks should, however, be added to the text. By principal axes of the integrant crystal, in metallic masses becoming crystallometrically arranged, under the influence of heat or pressure due to its motion, I do not necessarily mean the optic axis, even such determinable for opaque bodies, such as the metals, but that symmetric axis of the integral crystal, whose position, after consolidation of the mass, is found coincident with the direction in which the heat wave has passed out from the mass, if cooling, or into the mass, if heating; and which direction is necessarily that of least pressure within the mass, the pressure being that due to distortion or change of form, by contraction or expansion. As matter of observation, this is found to be the longest axis of the crystal in metals.

But, although not ascertainably the optic axis in metallic crystals, future investigation will most probably show, through such transparent bodies as assume in mass the same crystallometric arrangement, that the principal axis, as the term is used by me, has direct relations to the optic axis.

It is certain that it must have immediate relations to the axes of elasticity of Fresnel, which again are in direct connexion with the optic axes, as Savart has shown. The relation of these latter to local or unequal pressure within the mass has already formed the subject of masterly investigations by Seebeck, Biot, Fresnel, Brewster, and others; and the analogies between the optic effects due to pressure and to change of temperature have been lucidly pointed out by Sir John Herschell, who has well explained that in heating or cooling masses, such internal strains or pressures are produced by expansion or contraction as reduce the proximate cause of the phenomena simply to one of pressure; heat itself having (as inferable from those facts) no specific action on the crystalline arrangement, but being merely the means through which internal and unequal pressures are produced. Mitcherlich's facts, long since ascertained, as to the unequal expansion of crystals in certain systems in different axes, even when uniformly heated, indicate unequal elasticity in their respective axes, as well as unequal resistance to the transmission of the heat wave; the latter fact—the inequality of conducting power of crystalline bodies in different axes—is sustained by the researches of Senarmont ("Annal. de Chim." 3 ser. xxi. 457; xxii. 179; xxviii. 279), in papers of the highest interest. He even found that unequal pressure

in homogeneous uncrystallised solids, altered their conducting power in different directions.

These mutual relations are elucidated in Sir John Herschell's article Light, "Encyc. Britt." vol. iv.; arts. 1000, 1085 to 1097, 1113. They form at this moment the frontier and vantage ground of future conquest at once in physics and chemistry. (See also Maxwell's Papers on Elasticity, and on Faraday's Lines of Force, "Camb. Phil. Soc. Trans." December 10, 1855.)

It has been questioned to me how far the fundamental fact is established, that iron, in its several conditions of cast iron, steel, and especially of malleable iron, is truly crystalline at all; whether it may not be possible that the texture of a long, silky-fibred bar of rolled wrought iron is due simply to the extension and drawing out, long and fine, of a heterogeneous mixture of amorphous metal, and of included and uniformly distributed "cinder" (*i.e.* oxides, silicates, and carburets), which might be supposed to form together the mass as first withdrawn from the refinery or balling-furnace, much like as a mass of bird-lime and dry clay, diffused through it, would probably roll or draw out.

I cannot admit the force of the objection, or of the analogy.

All the evidence we possess is in favour of iron having a truly crystalline structure. This is the structure of all so-called elementary bodies, and assumed with distinctness (*cæteris paribus*) in proportion as they approach to chemical purity; not only the analogy here, but that nearer with all other metals, would be broken by such assumption, the crystallizing power being evidenced in all, though developed with very different facility, still in an unbroken chain, from bismuth and antimony, down to whichever may be held most difficult to obtain in crystals from fusion. But there is positive evidence of the power of cast-iron, of steel, and of malleable iron to assume the crystalline structure. The form of the integrant crystal is obvious; perfect crystals may be isolated; they possess the property of distinct cleavage in well-developed instances (Wöhler); and the fresh surfaces, often of great size, possess the perfection of plane and of polish that crystallization can alone confer. Other less broad and obvious characteristics, such as difference of resistance to the action of menstrua in different axes, might be urged. Or again, the difference of elasticity of (chemically the same) iron in different states of developement of the crystallization of the whole; and difference of elasticity in different axes in the same mass, following observable differences in the prevailing directions of the crystalline axes.

In a word, there appears no more good reason to doubt the true crystalline arrangement of the molecules of iron than there would be to doubt that an isolated octohedral crystal of native gold was truly a crystal, because, by the blow of a hammer, we can flatten it into a spangle. The masking circumstance is alike in both cases. Metallic

crystals are all more or less malleable; they are, therefore, susceptible of distortion (to almost any extent, in the most malleable metals), and of re-formation, without further external change in the mass.

But an additional argument may be drawn from Professor William Thompson's views as to the nature of the forces concerned in thermo-electric currents, from which it would seem to follow that iron, or any other body in which a thermo-electric current can be excited, can have none other but a crystalline arrangement. (Thompson, "Dynamic Theory of Heat," Phil. Mag. 1856.)

In addition to the several examples quoted of the arrangement of crystalline axes perpendicular to the bounding planes of the solid, I would remark a very interesting one, given by the late Professor Daniell, "Elem. of Chem. Phil.," sect. 117, p. 88:—If a parallelopiped of tin—hammered or cast, matters not—be placed in mercury for some time, the latter is absorbed gradually: it enters the mass by successive plane couches parallel to its surfaces; expansion is produced in the planes of these couches, and hence lines of least pressure perpendicular to the same. After a time, the parallelopiped is found split up into six pyramids, by planes penetrating from its edges, and intersecting within it,—their bases being the original sides of the solid; and each of these pyramids is found composed of crystals, whose longest axes are arranged perpendicular to the original sides, and parallel to each other; and into these integrant crystals each pyramid may be subdivided.

Here is a case in which chemical change—resulting in the formation of, no doubt, a definite amalgam—has resulted, owing to the peculiar circumstances of its formation in a state of crystalline aggregation, similar to that which mere change of temperature would have induced in the parallelopiped of tin, had the latter been large enough for internal strains to have so arisen.

Again, the following curious experiment, made by myself several years since, but not previously published:—If a portion of "Muntz patent yellow sheathing-metal" in the state in which it is used in common for ship's sheathing, bolts, &c. namely, in which it is tough, malleable, extremely flexible, and endowed with a distinct fibrous arrangement in the directions in which it has been laminated or rolled—if of this a small rod, or a narrow slip, be cut from a sheet, and plunged for a moment or two in a tolerably strong solution of nitrate of mercury, and then withdrawn, washed, and wiped dry, it will be found that it has almost instantaneously become rigid, and so brittle that it may now be broken into short bits between the fingers, whereas previously, reiterated bending backwards and forwards between the hands would have with difficulty broken it at all.

The surface of the metal is found slightly amalgamated; its fractures present crystalline planes, penetrating the solid in directions perpen-

dicular to its faces; and, on examination of the fracture with a lens, an extremely superficial, but real, penetration of the mercury between the surfaces of the crystals will be observed to have occurred.

The conditions here are varied. The phenomena occur with much greater, indeed with truly remarkable, rapidity, the transmutation from toughness to brittleness being instantaneous; but the results, and their explanation, are the same as in Daniell's experiment.

Chemical change, then, does not prevent this inversion of crystalline axis; on the contrary, if it induce the required condition of internal strain, it may produce the same crystalline arrangement that heating, or cooling, or local pressure can do.

Mineralogy and lithologic geology are full of examples of the play of these crystalline forces under the influence of pressure due to gravity, or to change of temperature; and some of its obscurest phenomena are yet destined to receive light from the application to them of the general law enunciated in the text.

What geologist is there who has not observed, that the integrant crystals, forming the mass of quartz and other such thin veins in igneous rocks, are all arranged in lines perpendicular to the bounding planes of the original fissure—the lines of least pressure in the mass, as it was heated or cooled by the surrounding rock?

Upon a greater scale, we find the metamorphic crystals of changed rock adjacent to dykes of igneous rocks—as the chalk penetrated by trap in Antrim,—stretching away from the walls of the dyke in lines perpendicular thereto; and the arrangement of the trap, so far as it is crystalline at the surfaces of contact, obeying the same law. In Scotland, coal converted naturally into coke, by intrusion of a trap-dyke, assumes the pseudo-crystalline structure known of it in planes of fracture perpendicular to the bounding planes. Perhaps even the yet unsolved mystery of the structure of columnar basalt may find its key and solution,—not *in* this law, but by views which it shall suggest; as well as the molecular conditions, upon the physical action of which the lamination and cleavage of the slaty and other rocks of apparently perfectly homogeneous material has depended; the directions of the pressures concerned in which Mr. Sharp has developed with so much ability.

The navigator in high latitudes has long been familiar with the dreaded fact, that the thawing iceberg, as it floats upon the ocean into warmer latitudes, often suddenly—without apparent external cause, or by any that shall produce the slightest vibration, such as the firing of a gun—splits up, and parts asunder into enormous spiriform masses, whose bounding planes are generally nearly, or quite, perpendicular to the surface of the sea, and which fall with fearful commotion, and stretch their lengths upon the bosom of the deep. The same law has acted here upon a still vaster scale: the whole berg, reduced nearly to its melting-

point, has received, by conduction from the ocean beneath, and from the air above, its heat in directions mainly vertical, and its splitting planes are so likewise; for the directions of greatest internal strains are, on the whole, horizontal. Its long fragments, if large enough, obey the same law, but in directions now at right angles to that in which it acted upon their parent berg. We may even imitate all these phenomena, upon a small scale, by heating a block of American ice slowly, by one of its flat surfaces, upon a heated plate of metal or of water; or we may observe them in play in the cross fractures of the thick ice of every pond, as it becomes rotten, and breaks up at the thaw.